GEOMORPHOLOGICAL STUDIES WITH SPECIAL REFERENCE TO RAVENOUS DEVELOPMENT IN PARTS OF BHIND, MORENA DISTRICTS OF CHAMBAL BASIN, M.P., USING REMOTE SENSING AND GIS TECHNIQUES

THESIS

SUBMITTED FOR THE AWARD OF THE DEGREE OF

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IN

GEOLOGY
(Remote Sensing)

By

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Certificate

This is to certify that the work carried in this thesis entitled ***"Geomorphological studies with special reference to ravenous development in parts of Bhind, Morena districts of Chambal basin, M.P., using Remote Sensing and GIS Techniques"*** is the original research work carried out and completed by **Miss. Alia Yusuf** under my supervision at the Department of Geology, Aligarh Muslim University, Aligarh, India. The research work presented here has not been submitted before for any other degree at this or any other University.

I allow **Miss. Alia Yusuf to** submit this thesis for the award of the degree of **Doctor of Philosophy** in **Geology** of the Aligarh Muslim University, Aligarh, India.

Dated: 9\7\14

(Prof. Liaqat Ali Khan Rao)
Supervisor

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LIST OF ABBREVIATIONS

ASTER	- Advanced Space borne Thermal Emission and Reflection Radiometer
CEC	- Cation Exchange Capacity
DEMs	- Digital Elevation Models
DN	- Digital Number
DRM	- District Resource Map
ESP	- Exchangeable Sodium Percentage
FCC	- False Colour Composite
GCPs	- Ground Control Points
GIS	- Geographical Information System
IRS	- Indian Remote Sensing Satellite
ISRO	- Indian Space Research Organization
LISS	- Linear Imaging Self Scanning Sensor
NASA	- National Aeronautics and Space Administration
PCA	- Principal Component Analysis
SAGA	- System for Automated Geoscientifc Analysis
SOI	- Survey of India
SRTM	- Shuttle Radar Topographic Mission
UTM	- Universal Transverse Mercator
WGS	- World Geodetic System

CHAPTER - I

Introduction

Introduction

1.1. General Statement

Ravenous tract of Chambal basin come into existence in geological past and the process of soil erosion resulted into bewildering network of gullies and ravines, aggravated with anthropogenic activity. Chambal basin appears to have been experiencing severe morphogenetic evolution resulting into regional stream rejuvenation and prominent incision of drainage. In the lower Chambal valley there is a gradual increase in depth of Quaternary sediments overlying the Vindhyan Supergroup and Gwalior Group of rocks which have been severely affected by epirogenic and endogenic forces resulting into intricate network of gullies and ravines. In Bhind and Morena districts the table land where rainfall, neotectonic activity, Chambal river and its tributaries have eroded the land resulting into huge cracks and valleys. These deep valleys are ravines and formed when the upper layer of vegetative cover is not strong enough and the roots of trees are unable to hold and bind the soil together. The role of river depth, meandering, sink hole, cracks, process of scouring greater than the process of silting in the river and its tributary in deep alluvial plains found to be the main reason of the deepening of the river, having direct bearing on the depth of ravines.

1.2. Location and Accessibility

The study area is a part of Bhind and Morena districts, located at the northern border of Madhya Pradesh. Bhind district lies between 25^0 55' and 26^0 48' north latitude and 78^0 12' and 79^0 05' east longitude. Morena district lies between 26^0 05' and 26^0 42' north latitudes and 77^0 05' and 78^0 30' east longitudes. The study area lies between 26^0 15' and 26^0 50' north latitude and 78^0 30' and 78^0 45' east longitudes covering an area of about 574 km^2 (Fig.1.1). The study area is included in Survey of India (SOI) toposheets number 54 J/9 and 54 J/10. Bhind district is bounded by Agra, Etawa, Jalaun and Jhansi districts of Uttar Pradesh and Datia , Gwalior and Morena districts of Madhya Pradesh. Morena district touches Dholpur (Rajasthan) in north-west and Pinnahat (Uttar Pradesh) in north-east and Bhind, Sheopur Gwalior and Shivpuri district of Madhya Pradesh.

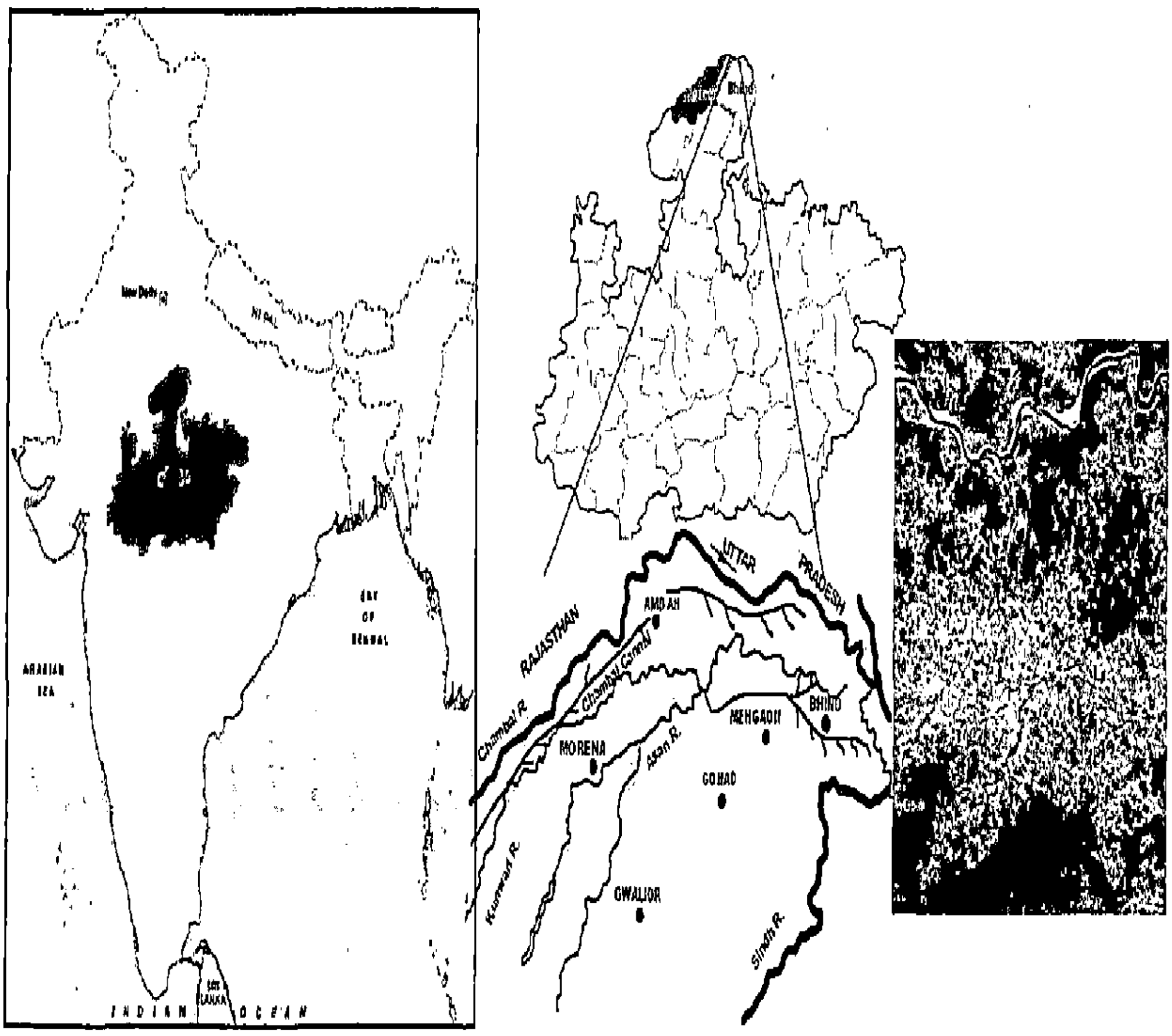


Fig. 1.1: Location Map of the Study Area

1.3. Physiography and Relief

Most part of Madhya Pradesh lies in the table land of Central India, interspersed with the mountains of the Vindhyan and Satpura ranges. The state of Madhya Pradesh is limited by upper Gangetic plain in north, Godavari valley in the south, plains of Gujarat in the west and Chhattisgarh in the south. High land of Madhya Pradesh can be divided into the plateau of Central India, the plateau of Bundelkhand, the plateau of Rewa and Panna, the plateau of Malwa, the Satpura and Maikal region and plateau of Baghelkhand. Narmada-Son rift valley divides these high lands into two parts (Fig.1.2).

Physiographically, the state of Madhya Pradesh is divided into four distinct regions namely; Satpura Range, Vindhyan Range, Bundelkhand Region and River Valleys. Satpura range trending east-west, with an average elevation of 600 meter above the mean sea level,whereas Vindhyan range trending ENE-WSW and occupies the central part of depositional basin.The undulating hillocks and ravines of Bundelkhand region are bounded by the Vindhyan plateaus in south, Yamuna river in north, Ken river in east, Betwa and Pahuj rivers in west. General slope of the region is S-N and the elevation ranges from 150m to more than 400 m above the msl. The River Valleys are limited and confined along the major rivers.

The northern plain comprises low lying areas around Gwalior and extends towards the north and north-east of the Bundelkhand region. The study area lies in the northern region of the lower Chambal basin, characterized by undulating topography formed by the alluvium and deep ravines. Physiographically, large part of Bhind district occupies vast older plain including infilled river beds, structural plains, structural hills and valleys with denudation slope, restricted to south-western part. The area is low lying flat terrain with gentle slope towards northeast. In the south-eastern part the elevation is as high as 190 m above the msl while in the north-western part as low as 149 m above the msl. The Vindhyan hills and valleys, range in elevation from 200 to more than 440 m above the msl in the east-southwestern part represents the physiography of Morena district. The ridges are represented by sandstone and valleys by shale. The minimum elevation is 150 meters above the msl with general slope towards north. Maximum height of the region is 600 m, but in north and north east the plain situated from 150 to 300 m above the msl (Fig.1.3).

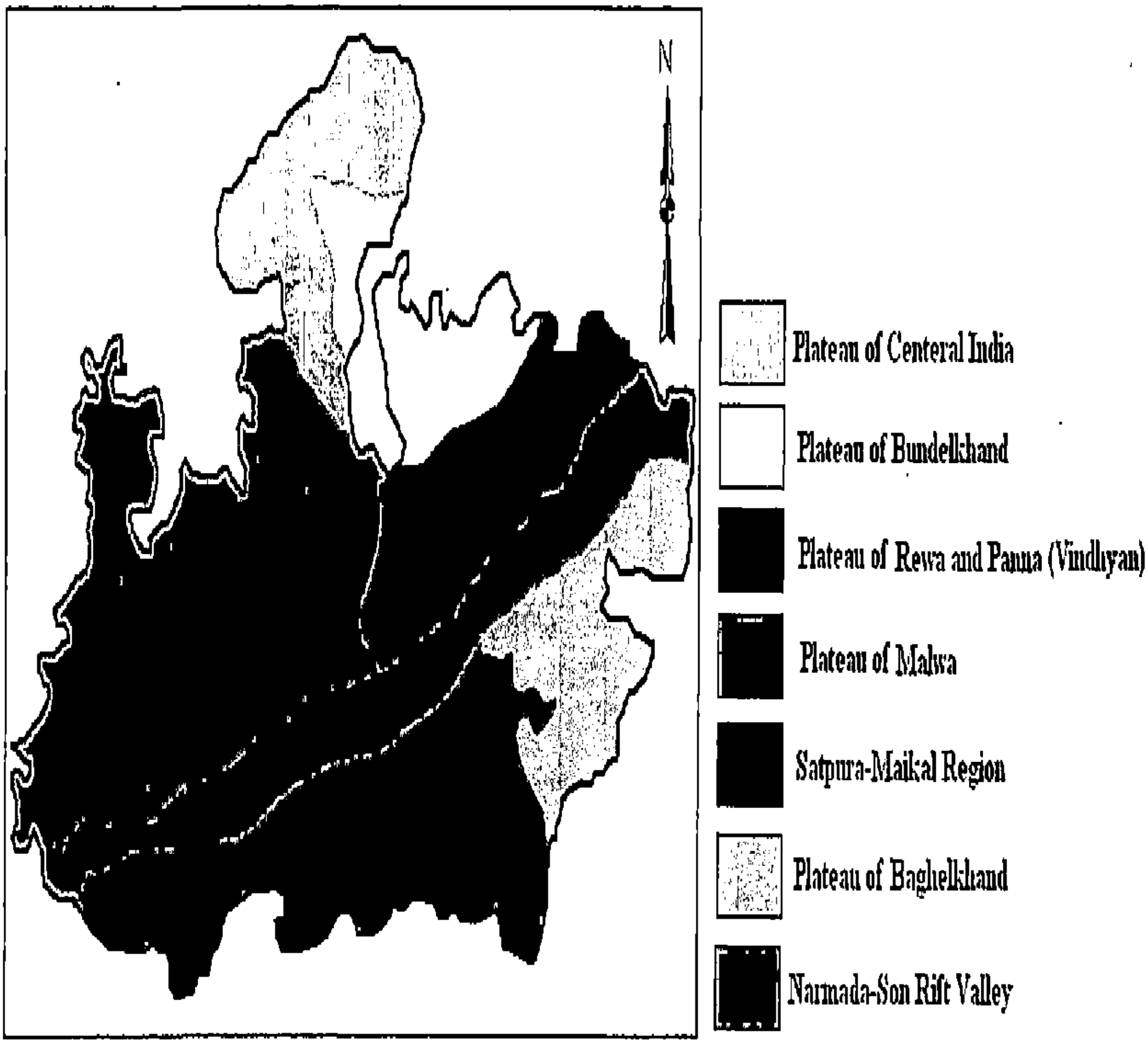


Fig.1.2: Plateau Region of Madhya Pradesh

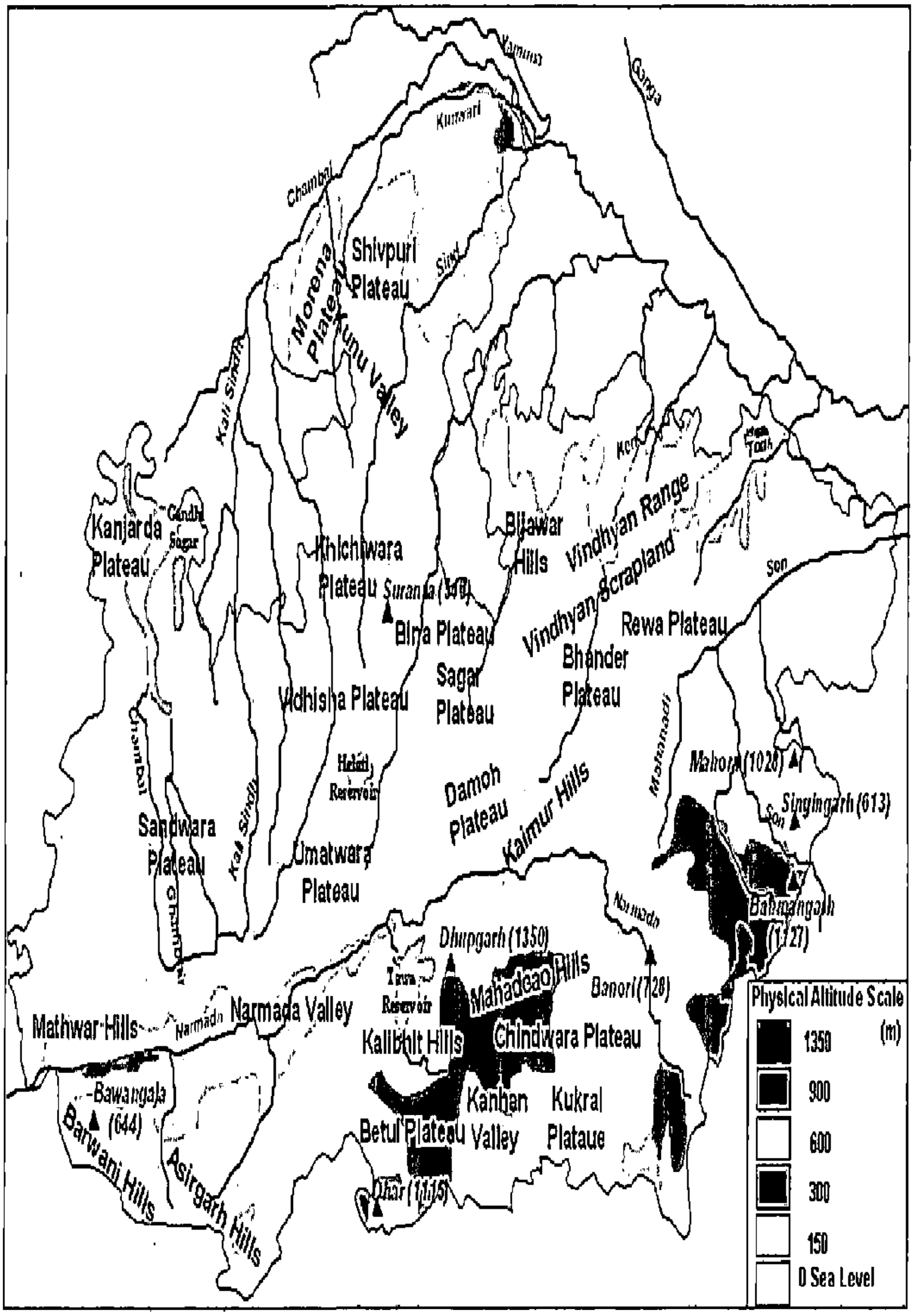


Fig. 1.3: Drainage and Relief Map of Madhya Pradesh

1.4. Climate and Rainfall

Madhya Pradesh enjoy tropical climate, cool and breezy in the central parts and humid in the eastern and southern regions. A year may be divided into four seasons. Cold winter season (December to February) followed by the summer season (March to about middle of June). The period from middle of June to September is the south-western monsoon season while October and November are the post monsoon or transition period. Average temperature in winter season ranges from 10° to 27° C (50° to 81° F) whereas, summers are hot, with an average temperature of 29° C (85° F) and reaches upto 48° C (118° F). During the monsoon season temperatures ranges from 19° to 30° C (66° to 86°F). Madhya Pradesh receives an average annual rainfall of about 1200 mm. The climate of Bhind and Morena district is hot summer with general dryness except during the south-west monsoon. Normal rainfall in Bhind is recorded as 705.1 mm and 712 mm in Morena. During the southwest monsoon season the relative humidity generally exceeds 83% (August). May is the driest period of summer and record relative humidity less than 26%. The average normal annual wind velocity of Bhind and Morena district is 6.4 km/hr.

1.5. Drainage

The main rivers in the region include Narmada, Tapi, Mahi and tributaries of Ganges like Chambal, Sindh, Betwa, Ken and Son (Fig.1.3). The northern part of the state is drained by Chambal, Betwa, Ken rivers and their tributaries, which flow northerly through Bundelkhand regions and join the Yamuna. The Son river flow ENE and join Ganges, whereas Narmada and Tapi flowing westerly between Satpura and Vindhayan ranges and draining to Arabian Sea. In Morena district, Chambal river follow a major lineament and main tributaries are Cham, Siwana, Ratan, Gambhir, Sipra, Kalisindh, Kural, Parbati and Banas rivers. In Bhind district the major tributaries of Chambal river include Asad, Besali and Sindh rivers and Pahuj and Kunwari rivers which are tributary of Sindh river.

1.6. Soil

Madhya Pradesh exhibits a variety of geological formations which are responsible for the formation of different type of soil ranging from rich clay to gravely. Inceptisols are the predominant soil type, covering 48%; followed by Entisols and Alfisols 10% each,

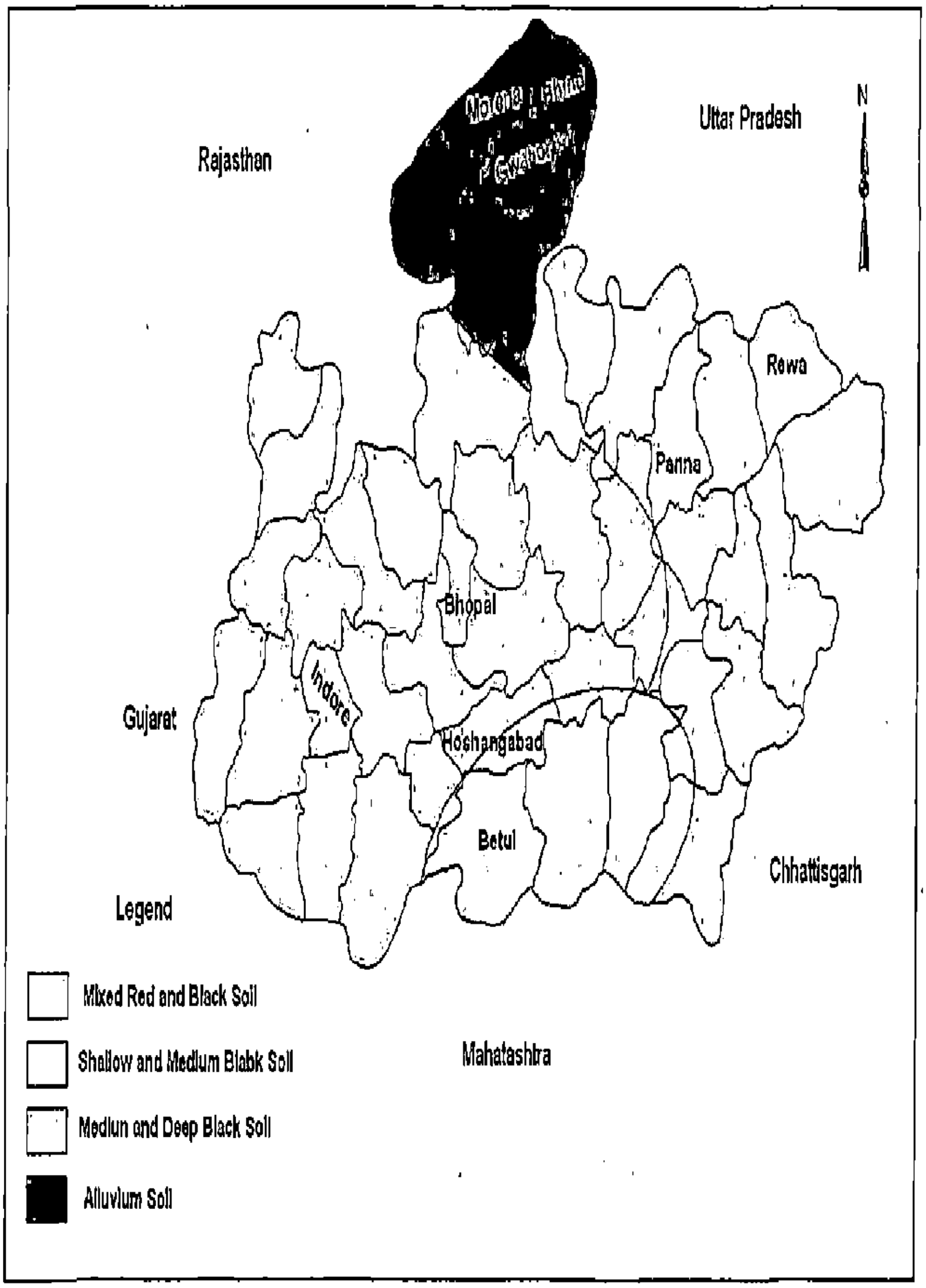


Fig. 1.4: Major Soil Group of Madhya Pradesh

Vertisols 21% and Mollisols <1% of the total geographical area of the state (Tamgadge et. al., 1996). The different types of soil including the study area are (a) Mixed red and black soil, (b) Shallow and medium black, (c) Medium and deep black and (d) Alluvial soil (Fig.1.4). Mixed red and black soil is mainly found in the northern districts viz; Rewa, Satna, Panna and Datia. Light coloured sandy, red and yellow soils are found suitable for rice cultivation. Shallow and medium black soil is mainly confined to the districts of Betul, Chundwara, Seoni and in pats of Hoshangabad, Balaghat and Mandla districts. The black medium and deep medium soil is found mainly in the Malwa region, Narmada valley and Satpura region, whereas mixed type of red, yellow and black soil is confined to the Vindhyan region and central part of the state. The north-western part of Morena, Bhind, Gwalior and Shivpuri is covered mainly with the alluvial soil, found mainly in the flood plain of Chambal and Kunwari rivers, favor the production of wheat, sugarcane and cotton.The soil of Bhind district is mainly deep alluvial soils, brown, and yellowish brown to dark grey brown in colour. Texture of soil varies from sandy loam (below 20% clay), loam (20-30% clay), clayey loam (30-40% clay) and clay (more than 40% clay). Sandy loam is mostly found in the district of Bhind and Morena whereas clayey loam is mainly found in Gohad and Malegaon block. In Morena district laterite forms flat and slightly undulating capping over the rocks belonging to the Vindhyan Supergroup. The soil is dark reddish brown and red in colour and mainly consists of haematite, goethite, gibbsite, opaques and quartz. Quaternary alluvium consisting of unconsolidated to consolidated yellowish brown sand, silt and clay with gravel and pebbles, forms the youngest formation exposed in the area. The thickness of the alluvium varies from a meter to more than 180 meters.

1.7. Vegetation

Major part of Bhind and Morena district is covered by forest and the plant species found in the area include Dhak (Butea menosperma), Aonia (Emblica officinalis), Arjun (Terminalia arjuna), Ashok (Polyathia lonifolia), Asna (Terminalia alata), Bahera (Turminalia bellirica), Bargad (Ficus bengalensis), Barhal (Artocarpus lakoocha), Bel (Aegle marmelos), Gular (Ficus glomerata), Gulmohar (Delonix regia), Eucalyptus (Eucalyptus longifolia), Jamun (Syzygium Cumini), Khair (Acacia indica), Mahua (Madhulka indica), Neem (Azadirachata indica), Pipal (Ficus religiosa), Siris (Albizzia lebbeck), Sesham (Dalbergia sissoo) and grasses like dub, baib, kans and spear grass. The main crops of the area are rice, wheat, pulses, sugarcane, soya bean and mustard.

1.8. Previous Work

It is paradoxical that the geomorphological studied in India have received the least attention from geographers and geologists. It is only within the last decade that the geographers realize the importance of this branch of environment sciences. Study of landforms is most vital and legitimate to study the landforms and land forming process to provide sound understanding of the physical landscape.

Geology of the area has been studied by Heron (1922) and Saxena (1975). Hydrogeomorphological mapping in parts of Bhind district has been carried out by Singh and Khare (2008), for groundwater prospect in the region. Extensive hydrogeological work in Bhind and Morena district is carried out by Central Groundwater Board (http://cgwb.gov.in). Geomorphological characterization and landscape evolution in and around Gwalior has been carried out by Dwivedi and Prabhaker (2010). The study of ravine is carried out by Ahmad (1968, 73) and Sharma (1968, 79 and 80) has given new dimension to the problem of ravine genesis and suggested that ravine erosion differ with different ecological setting in India. Ravine geomorphology has been studied by Gorrie (1957), Gadkary and Rao, (1955), Tejwani and Ahuja (1956), Kaul (1962), Mishra, et. al., (1967) and Bali (1972). Formation of ravines as a result of major soil erosion process is given by various soil scientists (Narain, et. al., 1979) and has been illustrated in the isoerodent map by Babu, et. al., (1978). Land degradation study of Chambal zone of Morena district has been carried out by Pani (2012) and Pani et. al.,(2001). Pattern of ravine genesis has been discussed by geographers, geologist and soil scientists (Tejwani, 1959, Sharma, 1968 and 1979, Pramila and Rai, 1972, Singh and Agnihotri, 1987). Singh and Singh (1982) analyzed the isostatic readjustment and rejuvenation of fluvial geomorphology of Chambal basin. Neotectonic implication for lower Chambal valley has been given by Pani, et. al., (2005) and change in stream dynamic of Chambal river have been analyzed by Shakti, et. al., (2011). The study also upholds the earlier view expressed by Sharma (1968, 80) in his study on geomorphology of the lower Chambal valley.

Photointerpretaion technique has been used by Kamphrost and Iyer (1972) for survey of ravines in India. Both satellite images and aerial photographs have been used for mapping and monitoring the ravines in various part of the country (Singh, 1984, Singh, 1977, Dhir, 1990, Karale, 1988, Pani and Mohapatra, 2001, Singh, et. al., 1987, Singh, et., al 1999 and Stephens and Chilar, 1981). Based on the slope, depth and stage of development a classification of ravines is given by Seth, et. al., (1969) and Hironi, (1991). Recently, various image processing techniques for the interpretation of satellite image (Pani, et. al., 2001) for ravine delineation and Interferometric Synthetic Aperture Radar (InSAR) data for characterization of ravines on the basis of density, depth and surface cover is given by Chatterjee, et. al., (2009).

Studies on watershed management measures around Yamuna–Chambal ravines region of Agra were carried out by Bhushan, et. al., (1997), Chhajawa in the Chambal ravines by Prasad, et. al., (1996) and Navamota area in Gujarat around Mahi ravines by Kurothe, et. al., (1997). Water quality analysis of Bhind and Morena district has been carried out by Chourasia (2003). Morphometric analysis of badland of Maharashtra is studied by Joshi, et. al., (2009), Yamuna badland by Rao, et. al., (2011) and Ansari, et. al., (2012). Basin morphometry of Maingra river in Gwalior district, M.P is carried out by Singh and Singh (2011).

Vegetation and flora of Chambal region in Bhind, Morena and Sheopur districts have been studied by Pathak (2013). Seth, et. al., (1969), Tejwani (1972), Bali and Karate (1977) and Dwivedi and Ramana (2003) and delineated the reclaimable group of ravines for agriculture. Society for Promotion of Wastelands Development Gwalior(SPWD and SAMBHAV, 2004) had initiated a watershed project in Pali Hamlet of Sunari Watershed.

1.9. Objective of the Present Study

Present study is conducted in parts of Bhind and Morena district which are severely affected by soil erosion and ravine formation along Chambal and Kunwari rivers. The study reviews the technical contributions made towards the study of ravine genesis carried out by the workers of soil conservation research, government of India in the light of the dissident views expressed by academic geoscientists. The present study also reviews the soil conservation establishments which will be major contributions to cost-effective ravine reclamation planning. However, it is emphasized that while great advances have been made towards technological remedies for ravine erosion, relatively little has been accomplished in the realm of social aspect.

The main objective of the present study:

2. To delineate and asses geomorphology of the study area.
3. To generate different thematic layers in GIS environment and generate data base.
4. To analyze and compare the change in ravine areas of Chambal and Kunwari river.
5. Soil characteristic study.
6. Morphology and genesis of ravines.

1.10. Scope of the Study

Present investigation is carried out to understand the mechanism and physio-chemical condition in which the ravines of Bhind and Morena district were formed. Present work is directed not only to study the geology, geomorphology and soil applying remote sensing and GIS techniques but to take a detail investigation of Chambal ravines with respect to their genesis, soil erosion and reclamation measures. Since ravines have good potential for crop and timber production, thus the study provides necessary information towards using these badland for better purposes.

CHAPTER - II

Stratigraphy and Geological Setup

Stratigraphy and Lithological Setup

6.1. General Statement

Stratigraphically the state of Madhya Pradesh is represented by rocks ranging in the age from Archean to Recent. Sediments belonging to the Gwalior Group deposited over the denudational surface of the Bundelkhand granite, blanketed by sandstones and shales of the Vindhyan Supergroup. The eastern most boundary of the Gwalior Group is truncated against the regional fault in the northeast–southwest flowing Sindh river. Further, east of Sindh river, rock units belonging to the Gwalior Group mainly covered by thick alluvium. The rocks of Gwalior Group are exposed in a prominent E–W trending scarp section which marks the unconformable contact with the basement of Bundelkhand Granite Gneiss Complex (BGGC). The Gwalior Group sediments divided into two Formations namely as Par Formation and Morar Formation. The basal Par Formation is about 200m thick and constitutes clastic areneceous-argillaceous rocks and mainly includes quartz pebble conglomerate, arkosic sandstone, matrix rich clayey sandstone, ferruginous sandstones, quartz arenites and shales. The Morar Formation is about 800m thick, conformably overlies the clastic Par Formation and includes ferruginous shale, black siliceous shale, two thin impersistent limestone units and a conspicuous kaolinitic clay bed at the base.

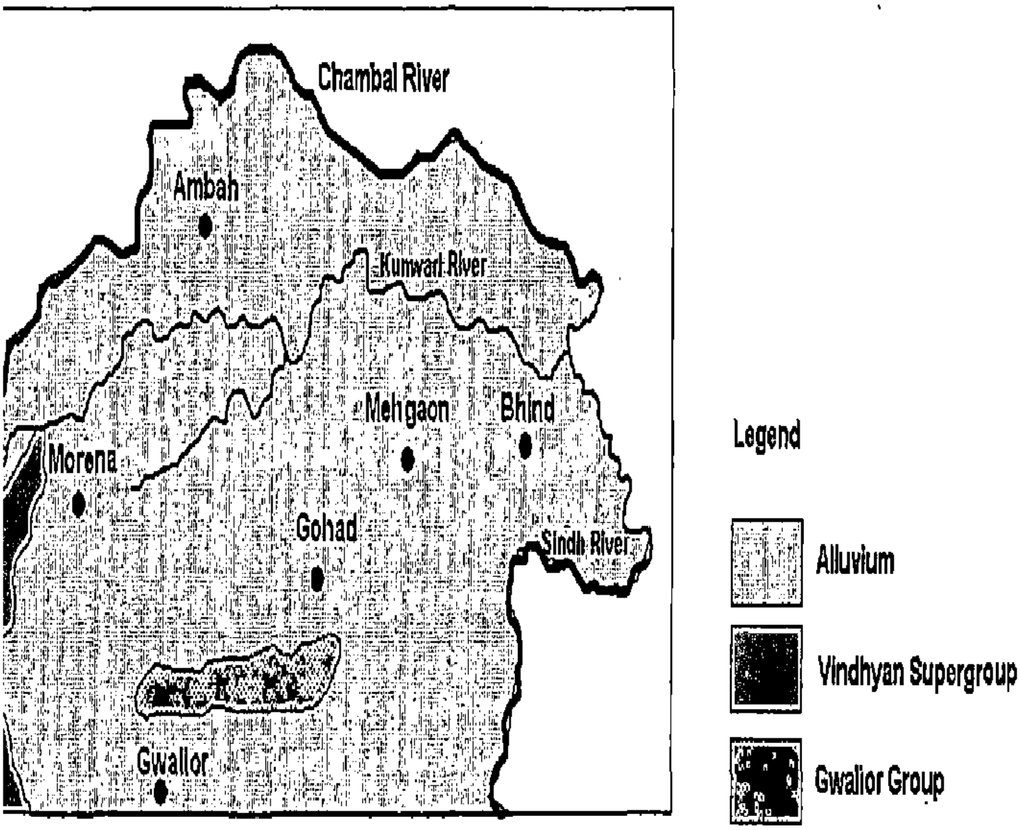
The Vindhyan Supergroup is divided into Lower Vindhyan and Upper Vindhyan. The Upper Vindhyan is stratigraphically known as Semri Group whereas Lower Vindhyan is sub-divided into Kaimur, Rewa and Bhander Groups, based on the major tectonic events (Auden, 1933, Mallet, 1869, Chaudhari et al., 1999; Prasad, 1984). The rocks belonging to the Semri Group are exposed towards east, along the outer rim of the depositional basin of Vindhyan sediments, while the rock units belonging to the Kaimur, Rewa and Bhander Groups, exposed in the central and western part of the basin. The sediments are largely unmetamorphosed and mostly undeformed except at some places. Local folds with limbs dipping around 10^0-30^0, frequently seen near the periphery and less frequently in the center.

Thick alluvium cover lies over the Vindhyan basement, constitute more than one horizon of gravel and at places cemented by carbonate matters, sand, silt and clay, overlying the lateritic gravel. Alluvium deposited by major rivers and their tributaries covering large area towards NE-SW (Fig 2.1). The soil in Morena and Bhind districts of Chambal basin is largely represented by altered shale and limestone of the underlying Bhander Group. Alluvial soil in the area recognized and grouped as older and newer alluvium. Low-lying younger floodplain alluvium is locally known as Khadar and older alluvium which is seldom liable to inundation is known as Bhanger. Khadar occupies the riparian flood plains and enriched by fresh silt deposits every year. It is light coloured and poor in calcareous matter, consist mainly sand, silt, mud and clay (Tiwari, 1984). A little of Khadar can be assigned to the Upper Pleistocene and most to the Recent age (Krishnan, 1968). Bhanger alluvium are level plains above the normal flood limit, dark in colour (pale reddish brown) generally rich in concretions and nodules of impure calcium carbonate (Mukherji, 1964). The main constituent of Bhanger is clayey loam and sandy loam of Middle and Upper Pleistocene periods. The bottom of the alluvium deposit is very irregular and at places exhibit, protruding of the Vindhyan rocks.

2.2. Regional Geology

2.2.1. Gwalior Group

The rock units belonging to the Gwalior Group mainly consist of sandstone, shale and traps forming east-west trending hill ranges in Gwalior, Datia and Bhind districts. These beds are unconformably overlain by Kaimur Group belonging to the Upper Vindhyan Supergroup. Lower Par Formation of the Gwalior Group represented by fine grained thin bedded sandstone and conglomerate. At depth these rocks are deposited over the denudated surface of Bundelkahand Granite. The Par Formation is overlain conformably by Morar Formation, consisting thin flaggy siliceous and ferruginous shale, interbanded with chert, hornstone and jasper and thin impersistent bands of limestone. The Morar Formation contains two zones of trap flows, where upper zone is more than 150 meters thick. At places bands and lenses of hematite in ferruginous shale have also been observed. The general sequence of Gwalior Group as given by Bajpai (1935) is presented in Table-2.1.



:gional Geology of the Area

Table.2.1. Generalized Lithostratigraphy of the Gwalior Group (After Bajpai, 1935)

Vindhyan Supergroup		
~~Unconformity~~~~		
Gwalior Group	Morar Formation	Ferruginous shale, slates, hornstone and jasper with trappean rock
	Par Formation	Sandstones and Quartzites
~~Unconformity~~~~		
Bundelkhand Granite Gneiss Complex (BGGC)		

2.2.2. Vindhyan Supergroup

Vindhyan Supergroup is represented by a thick pile of late Precambrian sedimentary rocks, comprise largely sandstone, shale and limestone, deposited in a shallow basin. The beds of sedimentary rocks are broadly sub-horizontal with low regional dips towards the centre of the basin. The Vindhyan Supergroup is divided into four Groups namely Semri, Kaimur, Rewa and Bhander in order of superposition. The generalized lithostratigraphy of the Vindhyan Supergroup (Srivastava, 2012) is given in Table.2.2.and discussed as:

2.2.2.1. Semri Group

The rock units belonging to the Semri Group are exposed mainly in Rewa, Sidhi, Shahdol and Jabalpur district in the east, Son river in Satna, Jabalpur and in the north of Satna, Panna and Chhatarpur districts respectively. The Semri Group consists mainly of sandstone, conglomerate, porcellanitic shale and limestone. The porcellanite and tuffaceous shale show volcanic activity during the earlier part of Semri period. (Mishra et. al. 2013)

Table-2.2: Generalized Lithostratigraphy of the Vindhyan Supergroup (After Srivastava 2012)

Supergroup		Group	Subgroup	Formation
Vindhyan Supergroup	Upper Vindhyan	Bhander Group		Dholpur Shale/ Bhavpura Shale
				Balwan Limestone
				Maihar Sandstone
				Sirbu Shale
				Bundi
				Bhander Limestone
				Ganurgarh Shale
		Rewa Group		Govindhgarh Sandstone
				Jhiri Shale
				Panna Shale
		Kaimur Group		Dhandraul Sandstone
				Scrap Sandstone and Conglomerate
				Bijagarh Shale Breccia
				Kaimur Sandstone and Shale
~~Unconformity~~~~~~				
	Lower Vindhyan	Semri Group	Rohtas Subgroup	Bhagwar Shale
				Rohtas Limestone
			Kheinjua Subgroup	Rampur Sandstone
				Salkan Limestone
				Koldaha Shale
			Deonar (Chopan porcellanite)	
			Mirzapur Subgroup	Kajrahat Limestone
				Arangi Formation
				Basal Conglomerate

2.2.2.2. Kaimur Group

The rock units belong to the Kaimur Group represented by sandstone and shale. The Kaimur Group in Bhind district is represented by sandstone, exposed mainly in the west of Malampur as a continuous hill range, extending in the west of Morena district as isolated hills (Fig.2.3). The sandstone is red to grayish in colour, medium to fine grained, hard and compact. The sandstone in Bhind district rests unconformably over the conglomerate bed of Gwalior Group (Table-2.3) The Kaimur Group in Morena district is represented by Dudauni sandstone and overlies the lower Vindhyan. The sandstone is white to dirty white in colour, fine to medium grained, thinly to thickly bedded and at places show intercalations of siltstone.

2.2.2.3. Rewa Group

The rock units belonging to the Rewa Group conformably overlies the rocks of the Kaimur Group, characterized by alternating shale and sandstone. Two lithologically similar shale formations viz. Panna shale and Jhiri shale are separated by sandstone formation. The Jhiri shale conformably overlies the Dudauni sandstone with a sharp contact. The shale is predominantly argillaceous in nature, splintery and thinly bedded, olive green to khaki, grey, chocolate brown to reddish brown in colour with minor interbands of siltstone containing numerous veins of calcite. Discontinuous thin conglomerate bands occur near the bottom of the Jhiri shales. The Upper Rewa sandstone occurs as indurate outcrop and succeeds immediately above soft Jhiri shale. The Upper Rewa sandstone is light grey to greenish grey, brown, pink, white to dirty white in colour, fine to medium grained and moderately sorted glauconitic sandstone. The quartzite is thickly bedded and shows ferruginous laminations along with glauconite grains which crop out at places between softer overlying Ganurgarh shale and underlying Jhiri shale.

2.2.2.4. Bhander Group

The rocks of Bhander Group gradually overlie the Rewa Group, represented by Ganurgarh shale, Lower Bhander limestone, Lower Bhander sandstone and Sirbu shales (Table-2.4). The Ganurgarh shale forms the lower most litho unit of Bhander Group which is greyish green, purplish, reddish brown to dark brown in colour, soft, splintery and finely laminated. At places shale is ferruginous, arenaceous and calcareous towards the top. Ganuragarh shale shows a gradational contact and interleaf with Lower Bhander limestone. Lower Bhander limestone is most persistence and form marker horizon of the Upper Vindhyans and showing conformable relationship with the lower and upper lithounits. The limestone is ash in colour, fine grained, thinly to thickly bedded and shows elephant skin weathering. The Lower Bhander sandstone is exposed in the western part of the area, is dirty white, pinkish to light brown in colour, compact and fine to medium grained. The Sirbu shale is greenish to greenish blue, pale grey, purple red and brown in colour, thinly bedded, splintery and ferruginous in nature and at places show interbands of siltstone. Lithologically, Sirbu shale is red and olive in colour and at places more sandy than Jhiri shale. Laterites of Cenozoic age overlies the Sirbu shale is dark reddish brown and red in colour, consist of limonite, goethite, gibbsite, some opaque mineral and few quartz grains.

2.2.3. Alluvium

Middle to Late Pleistocene sediments is classified as Older Alluvium while Holocene sediments classified as newer or Younger Alluvium (Prasad and Kar, 2005). Pleistocene to Sub-recent alluvium in Chambal valley is represented by Older Alluvium with extensive development of kankar (Heron 1953). The alluvium covers a major part of the district, overlaying the rocks belonging to the Vindhyan Supergroup and limited along the bank of major rivers (Fig.2.2 and 2.3). The alluvium in the area of study is broadly divided as Older Alluvium and Younger Alluvium.

2.2.3.1. Older Alluvium

The Older Alluvium is classified as Banda and Varanasi Alluvium (Table-2.3) in the study area (Geological Survey of India, 2000) deposited over the tableland (Pl.I, Fig.1) between Chambal and Kunwari river (Fig.2.3). The Banda Alluvium consisting silt, clay, quartzo-felspathic sand and ferruginous nodules, exposed in the southern bank of Chambal and along both the bank of Kunwari river. Varanasi alluvium comprises oxidized silt, subordinate sand with kankar and ferruginous nodules. The Older Alluvium is mainly traceable in the western, south-western and in intervening plain areas between Kunwari and Chambal river. Older Alluvium is brownish to yellowish brown in colour, fine loams to coarse loams and slightly to moderately acidic. Near village Ater (Fig. 2.2) below the surface of recent deposit, the sub-recent conglomerate possesses kankar

Table-2.3: Stratigraphy and Lithology of Bhind district (After GSI, 2000)

Stratigraphy		Lithology
Younger Alluvium	Sindh Surface	Channel Alluvium Terrace Alluvium
	Jaswant nagar Surface	Loose, unconsolidated rock debris
Older Alluvium	Varanasi alluvium	Sand oxidized calcareous nodules fossiliferous boulder bed at bottom
	Banda Alluvium	Sand and Silt
Vindhyan Supergroup	Kaimur Group	Sandstone and minor shale bands
Gwalior Group	Biraoli Formation	Shale Limestone Band Jaspillite Basic Sills
	Sithauli Formation	Ferruginous Shale Chert Limestone lenses
	Sitla Formation	Ferruginous Shale Iron ore lenses
	Singpur Formation	Sandstone Shale Basal Conglomerate

(Calcareous nodules) exhibited along the bank of Chambal and its tributaries.

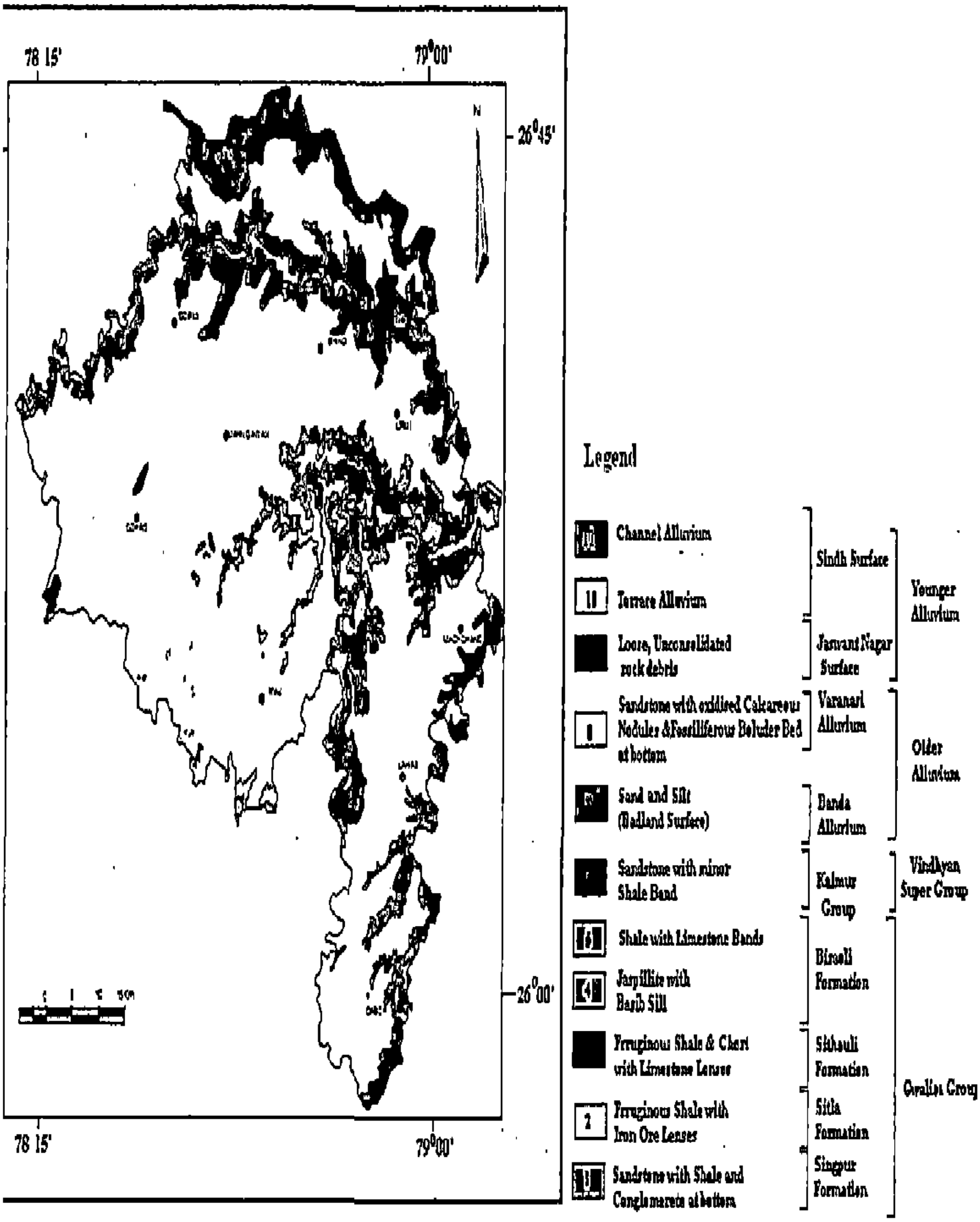
2.2.3.2. Younger Alluvium

Younger Alluvium is grey, red to brownish red in colour, composed of quartzo-felspathic and micaceous sand and silt, deeply incised by Chambal and Kunwari river displaying older alluvium at the valley wall. Younger alluvium is mostly composed of sandy to silty loams, slightly acidic to neutral in nature. The younger alluvium is classified into Jaswant Nagar and Sindh Surface. Jaswant Nagar surface comprises loose and unconsolidated rock debris mainly colluviums, which occurs at 15 km southwest of Gohad. Sindh surface occupies terraces on either side of the Chambal and Kunwari rivers and known as Terrace Alluvium. However, channel alluvium of Sindh surface is found on the slip off slope and in the river bed (Fig.2.2).

2.3. Geology of the Study area

Systematic geological mapping in and around Bhind and Morena districts were carried out by Geological Survey of India in 2000 and 2004 respectively. The stratigraphy and lithologial characters of Bhind and Morena districts are given in Table 2.3 and Table 2.4 and geological map of the districts are illustrated in Fig.2.2 and Fig.2.3 respectively. The geological formation of the study area is dominated by the Quaternary Alluvium resting over the Vindhyan Supergroup and Gwalior Group of rocks. The outcrop of Vindhyan Supergroup exposed in the western part of Gohad tehsil, Bhind district, forming basement over which alluvium is deposited. The Vindhyan sandstone in the area is hard, compact and devoid of weaker zones. In Morena district the alluvium overlies the irregular Vindhyan basement comprising of shale and sandstone. Shale is light coloured and highly weathered, exposed at the walls of river valley and overlain by alluvium. The alluvium deposits appear in sequel of Indo-Gangetic alluvium, accumulated in the drainage basins of the Chambal and Kunwari rivers. The alluvium varies in colour from brown, yellowish brown to dark grey brown while texture varies from sandy loam, loam, clay loam to clayey. Lithostatigraphy of the study area is summarized and given in Table.2.5.

Geological map of the study area (Fig.2.4) is prepared by georeferencing and tracing the map using district resource map (DRM, GSI, 2000 and 2004) of Bhind and Morena districts. Modifications are made in the original map on the basis of spectral



2: Geological Map of Bhind District (GSI, 2000)

Table-2.4: Stratigraphy and Lithology of Morena District (After GSI, 2004)

	Stratigraphy	Lithology
	Alluvium	Unconsolidated and consolidated sand, silt and clay Gravel and Pebble
	Laterite	Limonite Goethite Gibbsite Opaque mineral Few quartz grains
VINDHYAN SUPERGROUP	Bhander Group	Sirbu Shale Lower Bhander Sandstone Lower Bhander Limestone Ganurgarh Shale
	Rewa Group	Upper Rewa Sandstone Jhiri Shale
	Kaimur Group	Dudauni Sandstone

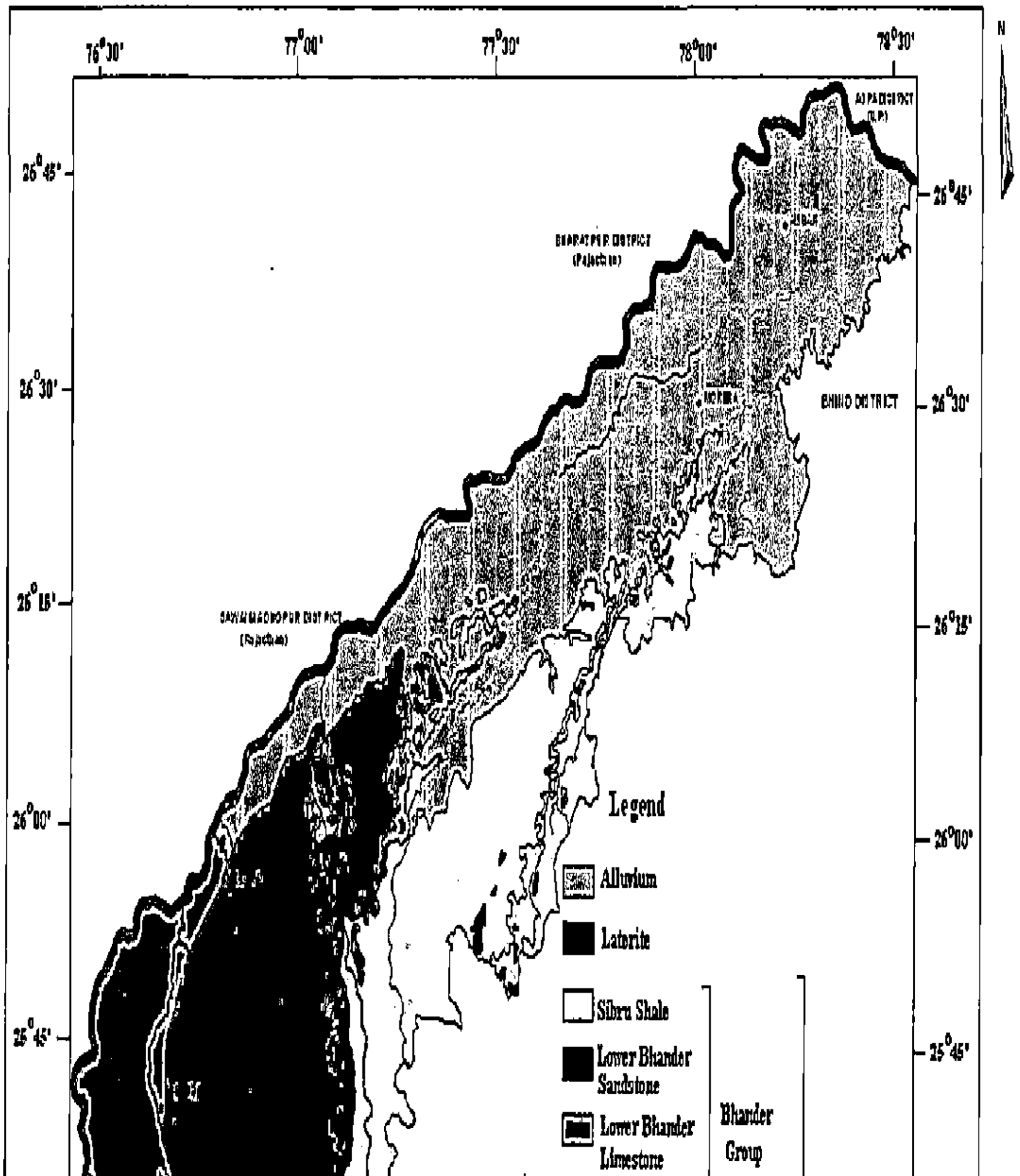


Fig. 2.3: Geological Map of Morena District (GSI, 2004)

Table-2.5: Lithostatigraphy of the Study Area

Stratigraphy		Lithounit
Younger Alluvium	Sindh Surface	Channel Alluvium Terrace Alluvium
Older Alluvium	Varanasi Alluvium	Sand Calcareous Nodule Fossiliferous Boulder bed
	Banda Alluvium	Sand and Silt
	Vindhyan Supergroup/ Gwalior Group	

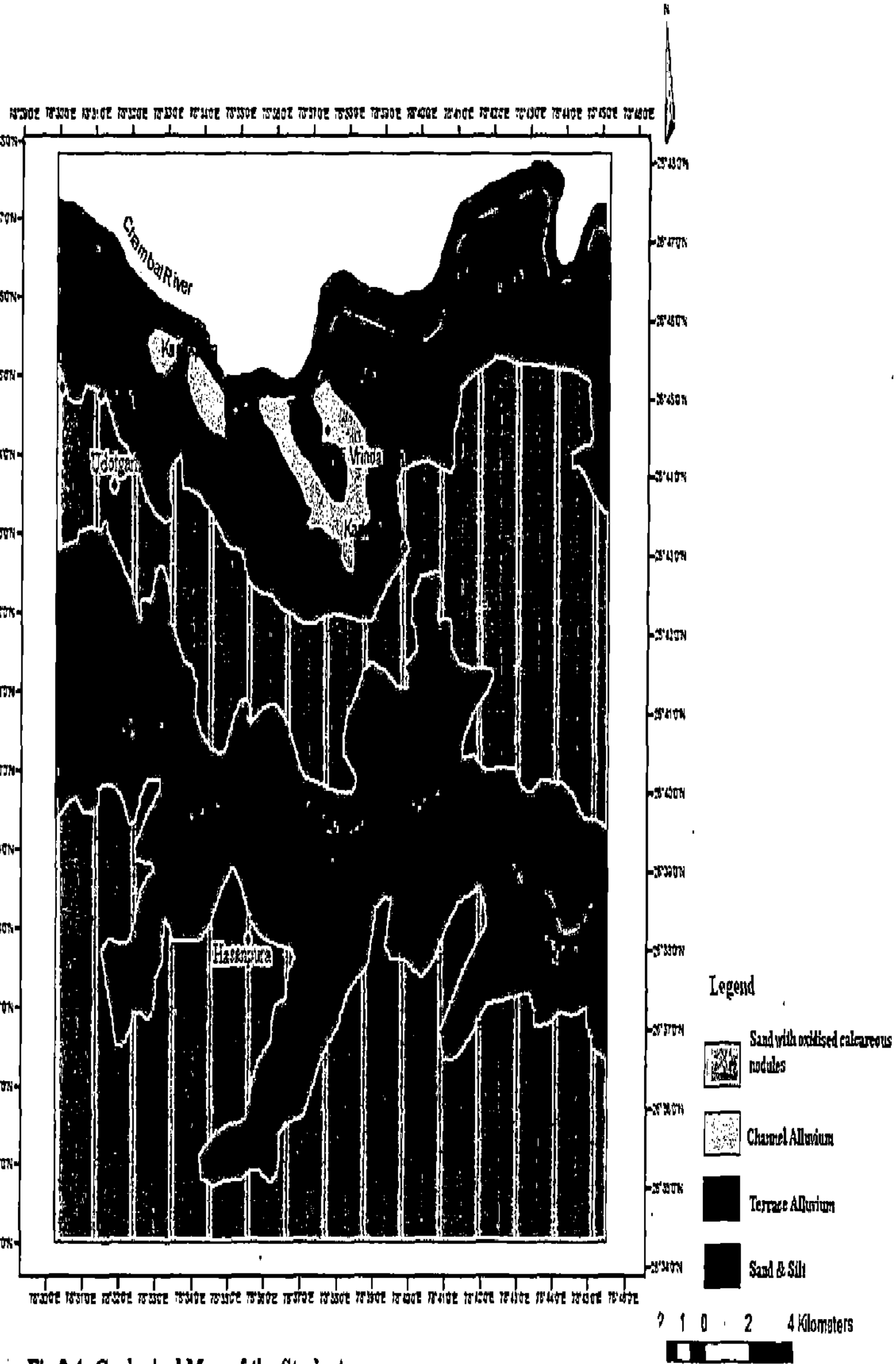


Fig.2.4: Geological Map of the Study Area

signature of IRS-P6 LISS-III since DRM is prepared on large scale. Some discrepancies are found when overlying the georeferenced district resource maps on to the satellite image. Thereafter large scale modified geological map of the study area is prepared based on spectral signature of the satellite image. Banda Alluvium consisting sand and silt of badland surface, represents the lower litho unit of the Older Alluvium. The quartzo-feldspathic sand is medium to coarse grained with ferruginous nodules at places. Geomorphologically, alluvium deposit referred as Varanasi Alluvium, invades the older alluvial plain and bounded by the older Banda Alluvium.

The Varanasi Alluvium forms elevated plain between Chambal and Kunwari rivers in the study area. The alluvium is dominated by clay, silt, sand and show polycyclic sequence of sand and clay (Pl.I, Fig.2). Chambal Valley shows presence of sand and silt layer between Older and Younger Alluvium (Pl.II, Fig.1). Clay loam horizon intermixes with calcareous and siliceous concretion locally known as kankar, noted in between the alluvium layers. This hard kankar pan restricts the downward percolation of groundwater and promotes horizontal flow along the slope toward the river. Terrace Alluvium is restricted along the Kunwari river and is conspicuously absent along the Chambal river. The Channel Alluvium of Sindh Surface comprises quartzo-feldspathic and micaceous sand and silt, occurs to the west of Ater village along Chambal river. Presence of lower litho unit of Older Alluvium (Banda Alluvium) adjacent to upper litho unit of Younger Alluvium (Channel alluvium) indicates baring lithology of the area. The study area is characterized by deep ravines presenting varying extent and thickness of alluvium.

CHAPTER – III

Materials and Methods

Materials and Methods

3.1. Data Acquisition

The systematic approach involving various steps of acquiring the required data from the concerned sources, its processing and interpretation, generation of thematic maps using satellite data, field visits etc, were adapted to carry out the present study as:

1. The available published and unpublished literature, technical reports, special volumes and research papers of national and international journal relevant to the present work and study area were collected and studied thoroughly.
2. Freely available ASTER DEM elevation data on 30 meter spatial resolution for study area was downloaded (http://www.gdem.aster.ersdac.or.jp/search.jsp) to generate different terrain components like elevation, slope, aspect, basin boundary etc.
3. The ortho-rectified Landsat ETM+ satellite data of the study area, available in public domain under NASA sponsored Global Land Cover Facility (GLCF), at University of Maryland website http://glcf.umiacs.umd.edu/index.shtml, was downloaded for year 1990 and 2006 corresponding to path-row number 145-42 for change detection analysis and for reference purpose.
4. IRS-P6 LISS-III data corresponding to the path-row 98-53 was used in MPCST, Bhopal, of year 2007 for preparation of various thematic maps and was further processed for geomorphic classification.
5. Study area falls in four tile of CARTOSAT-1 (IRS-P5) pan data of 2.5m resolution corresponding to the path-row number 534-274, 534-275, 535-274 and 535-275 were used for geomorphological mapping.
6. The required maps of the study area published in project reports, government reports and other collateral data were used in the present study.
7. Microsoft Excel module from MS-Office 2007 software program was used for making various calculations and plotting graphs. Various GIS software's utilized for the study are, Arc-View 3.2, ArcMAP 9.3, ArcGIS 10, ERDAS IMAGINE 2011, SAGA 2.0 (available at http://www.saga-gis.uni-goettingen.de/html.index.hph), Global Mapper v14.1, 3DEM 10.0.0.142 (available at http://www.visualization

software.com/3dem.html) and Geographic Translator 2.3 (available at http://earth-info.nga.mil/gandg/geotrans). The last four software's are open source software's, available for free download from the aforesaid websites.

3.2. Characteristic of CARTOSAT Data

CARTOSAT series of satellites with stereo mapping capabilities have become main impetus towards large scale mapping for urban and rural applications. In May 2005, the Indian Space Research Organization (ISRO) launched its CARTOSAT-1 satellite, which carries two cameras that acquire panchromatic stereoscopic images in the visible region of the electromagnetic spectrum. CARTOSAT -1 (IRS-P5) is the first satellite of ISRO designed to provide high resolution along-track stereo imagery for mapping applications. The platform contains two panchromatic cameras payloads with +26° and –5° tilted with respect to river. The base to height ratio is about 0.62.

3.3. Methodology

Various image processing techniques have been used for the identification and delineation of different geomorphological units, ravines and gully erosion. Methodology adopted for the present study is summarized and given in Fig. 3.1. Basically, all satellite image processing operations can be grouped into three categories: Image Rectification and Restoration, Enhancement and Information Extraction. Image Rectification and Restoration refers to the initial processing of raw image data for correction of geometric distortion. The data is radiometrically calibrated to eliminate noise present in the data. The enhancement procedures are applied to image data in order to effectively display the data for subsequent visual interpretation. It involves techniques for increasing the visual distinction between features in a scene. The objective of the information extraction operations is to replace visual analysis of the image data with quantitative techniques for automating the identification of features in a scene.

3.4. Preprocessing and Preparing Data for Image Processing

Geo-rectification is the correction of skew caused by the earth's curvature in raw satellite images. This is the first step which is adopted for the processing of satellite

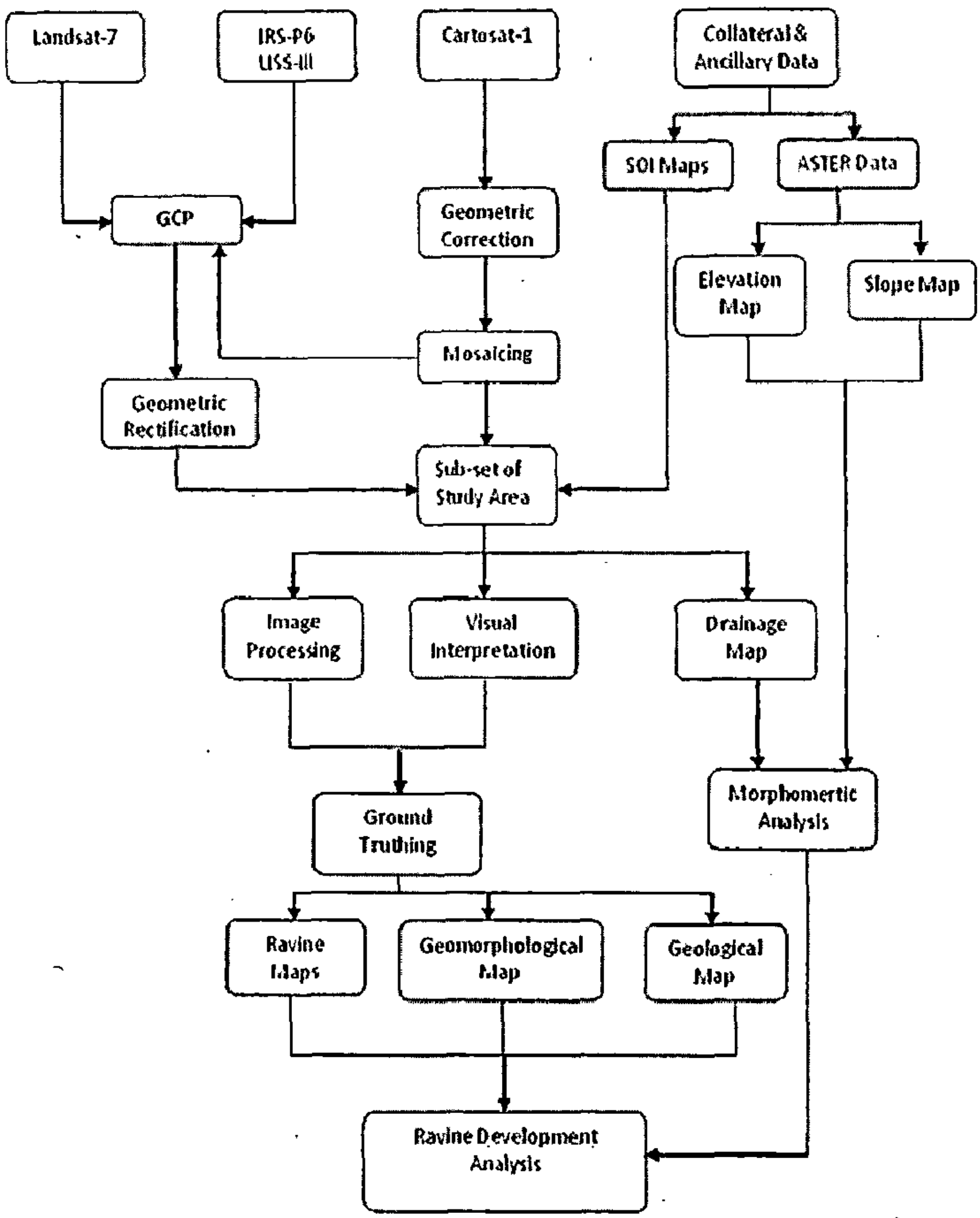


Fig.3.1: Diagram Showing Methodology of the Work Done

image to convert the raw data into usable form. It establishes the image in the correct spatial location and orientation. Raw Pan Images of CARTOSAT-1 was digitally rectified and geo-referenced by taking LISS-III multi-spectral image as a reference image in ERDAS IMAGINE 2011 through an image to image tie down by identifying ground control points (GCPs). Geometric distortions manifest themselves as errors in the position of a pixel relative to other pixels in the scene and with respect to their absolute position within some defined map projection (Minakshi, 2003). The image was radiometrically and geometrically corrected and rectified according to the World Geodetic Survey 1984 (WGS84) datum and the Universal Transverse Mercator (UTM) coordinate system.

The following steps have been taken for Geometric Correction of CARTOSAT Pan Data:

1. ERDAS IMAGINE 9.1 software suit was used for the rectification and geo-referencing of CARTOSAT -1 image.
2. Several clearly identifiable points known as Ground Control Points (GCPs) in the distorted CARTOSAT -1 image were identified from the LISS-III.
3. The process of image to image rectification is used by obtaining GCPs from geometrically corrected LISS-III image and matching them to their true position in ground co-ordinate.

3.4.1. Sub-set and Mosaicing

A common subset of the study area was extracted from the entire scene of LISS-III image corresponding to path-row 98-53 in Erdas Imagine 9.1 Data Preparation workstation. The clipped image was then exported as .img file for processing and classification purpose. The study area covers four scene of high resolution CARTOSAT-1 satellite. A mosaic of images is prepared by matching and splicing together individual image. The geo-registered images were mosaic together and then sub-set was clipped in Data Preparation Work Station of Erdas Imagine 9.1Software.

3.5. Image Processing Technique for Visual Interpretation

Image processing techniques improve the quality of an image as perceived by human eye. These techniques are most useful because many satellite images when examined in a colour display give inadequate information for image interpretation. In order to enhance different geomorphic features and landforms using digital data, different band combination, False Colour Composite (FCC), ratio image, contrast enhancement, pan sharpening, anomaly detection and mathematical edge enhancement filters were used. To assess the maximum information content in one image, Principal Component Analysis (PCA) of multi band data was carried out using PCA algorithm to generate output. Colour composites of principal component images offered greater help in the extraction of area of gully erosion with different intensity. These composites show better contrast to detect and distinguish the differences in tonal and spectral characters of the features present in the area. Different image processing techniques were used for the identification of various features present in the study area.

3.5.1. Colour Composite

While displaying the different bands of a multispectral data set, images obtained in different bands are displayed in image planes (other than their own). The colour composite is regarded as False Colour Composite (FCC). This composite image can be used for various processing technique to extract the required information of the study area. LISS-III image with 4 bands and 7 bands of Landsat ETM+ images were analyzed in various band combinations in order to derive maximum information from the multi-spectral image.

3.5.2. Contrast Enhancement

There is a strong influence of contrast ratio on resolving power and detection capability of images. Linear contrast stretches is the simplest contrast stretch algorithm and have been used to enhance contrast of pan image of CARTOSAT-1 data in the present study with 2% starching to improve the visibility of features (Fig.3.2). Due to low contrast in the tile 534-275 this tile is linearly stretched.

This contrast enhancement technique modifies the original Digital Number value of the image and DN value in the low end of the original histogram is assigned to extreme black and a value at the high end is assigned extreme white. All the other values are modified accordingly and distributed linearly. The improved contrast ratio of the image with linear contrast stretch enhanced different features on the map.

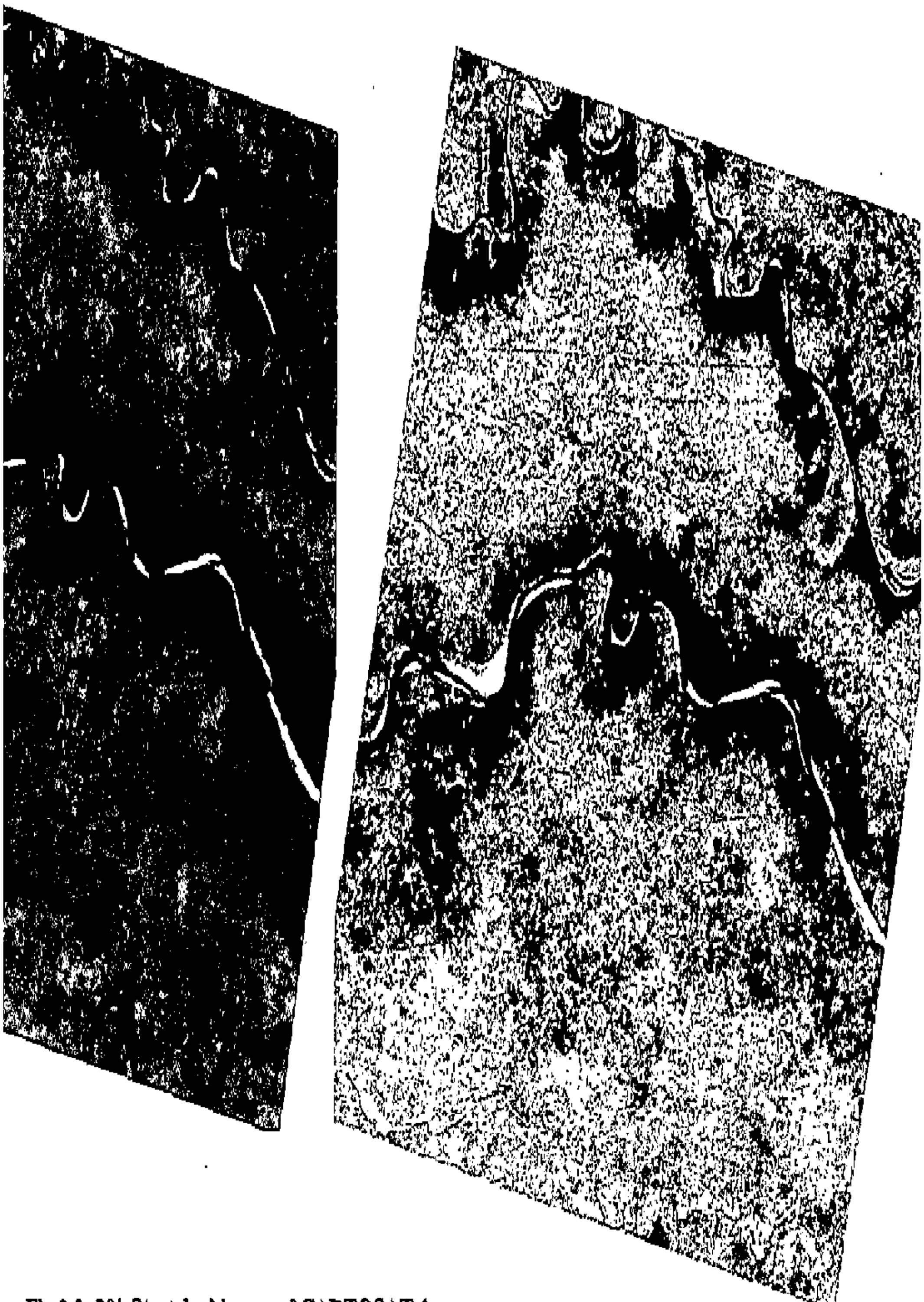


Fig.3.2: 2% Stretched image of CARTOSAT-1

3.5.3. Pan-Sharpening

CARTOSAT-1 has high resolution panchromatic band and LISS-III has a lower resolution multispectral bands where the pixel size is a multiple of pixel size of the pan band. Colour image show better detail than panchromatic image, hence better suited for mapping purpose or simply as a backdrop to vectors is obtained with the higher spatial resolution allowing more details. The CARTOSAT-1 image was first orthorectified to ensure that it exactly co-registers with LISS-III image and pan sharpen image was created (Fig.3.3).

3.5.4. Principal Component Analysis

The aim of principal component analysis (PCA) technique is to recognize the data so that they are no longer correlated. When applied to a multispectral data comprising multiple bands, it concentrates almost all the information in the first three or four components. The other components are generally noises, hence it also help in noise reduction processes and compresses the data into useful format only. PC-3 image (Fig.3.4) is obtained in present study to identify older alluvium zone from ravine/gullied land. PC-3 image is also helpful in identification of cultivated land within the ravine zone by light pink colour of buildup area with blue hue. PCA is a common remote sensing technique used to analyze multispectral remotely sensed image by transforming the raw image to new linear band combinations that may be more interpretable than the original image (Singh and Harrison 1985).

3.5.5. Anomaly Detection

In order to find out anomaly in large data set is an important as well as essential to filter the background noise and highlight the important information. Detecting underground structure as well as surface features with unusual chemical composition, texture and density called geo-anomalies, are important for determining the genesis of geology as well as detection of natural resources (Gartley and Basener, 2009). It helps in detecting signatures which are spectrally distinct from surrounding (Chang and Chiang, 2002). This technique is used to identify terrace zone and younger alluvium deposit with the ravine and gullied zone of Kunwari river. In the rugged terrain of Kunwari ravines, these deposits are smooth and stand out as anomaly image (Fig.3.5).

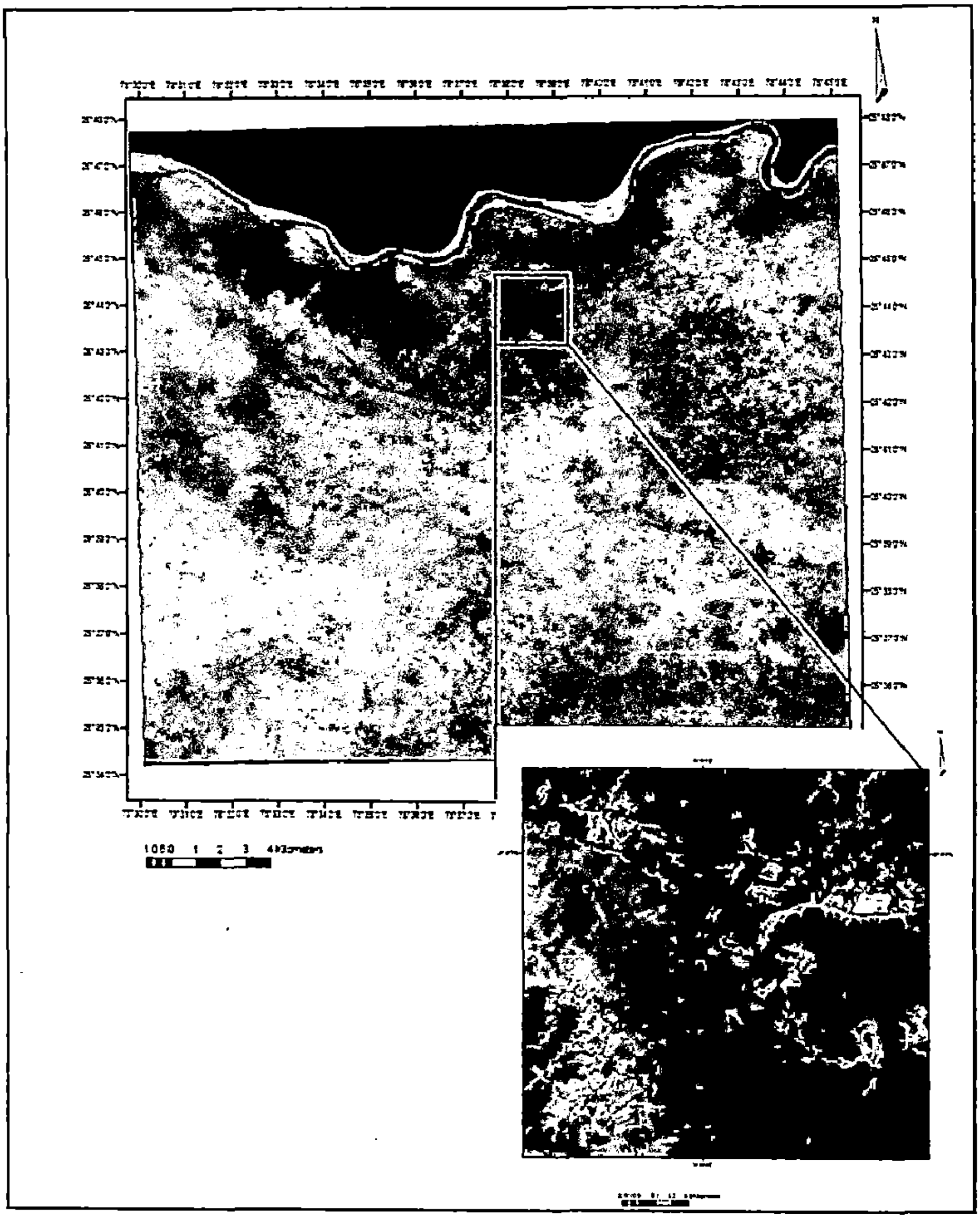


Fig.3.3: Mosaic- Pan Sharpen Image of the Study Area

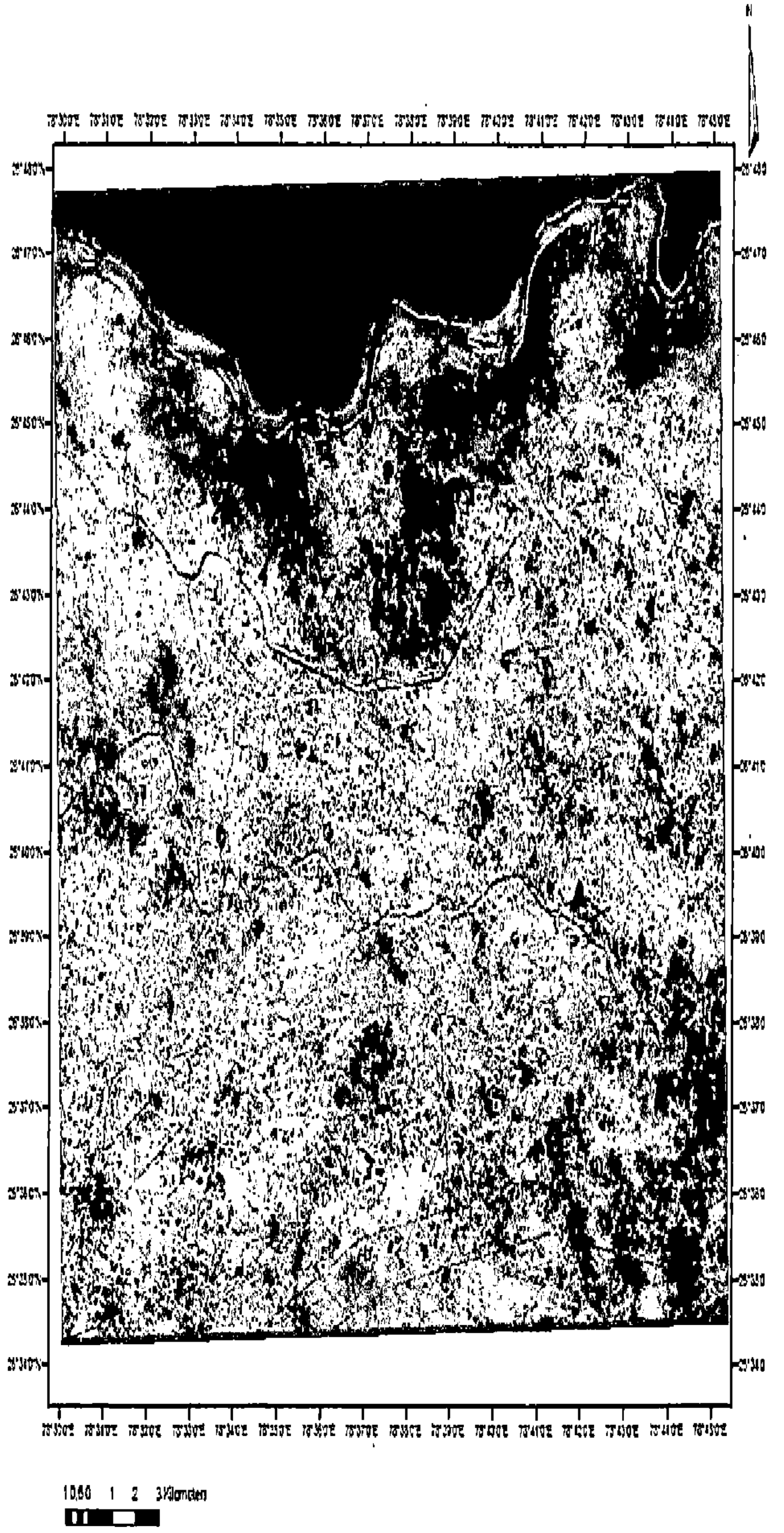


Fig.3.4: Principal Component -3, image of the Study Area

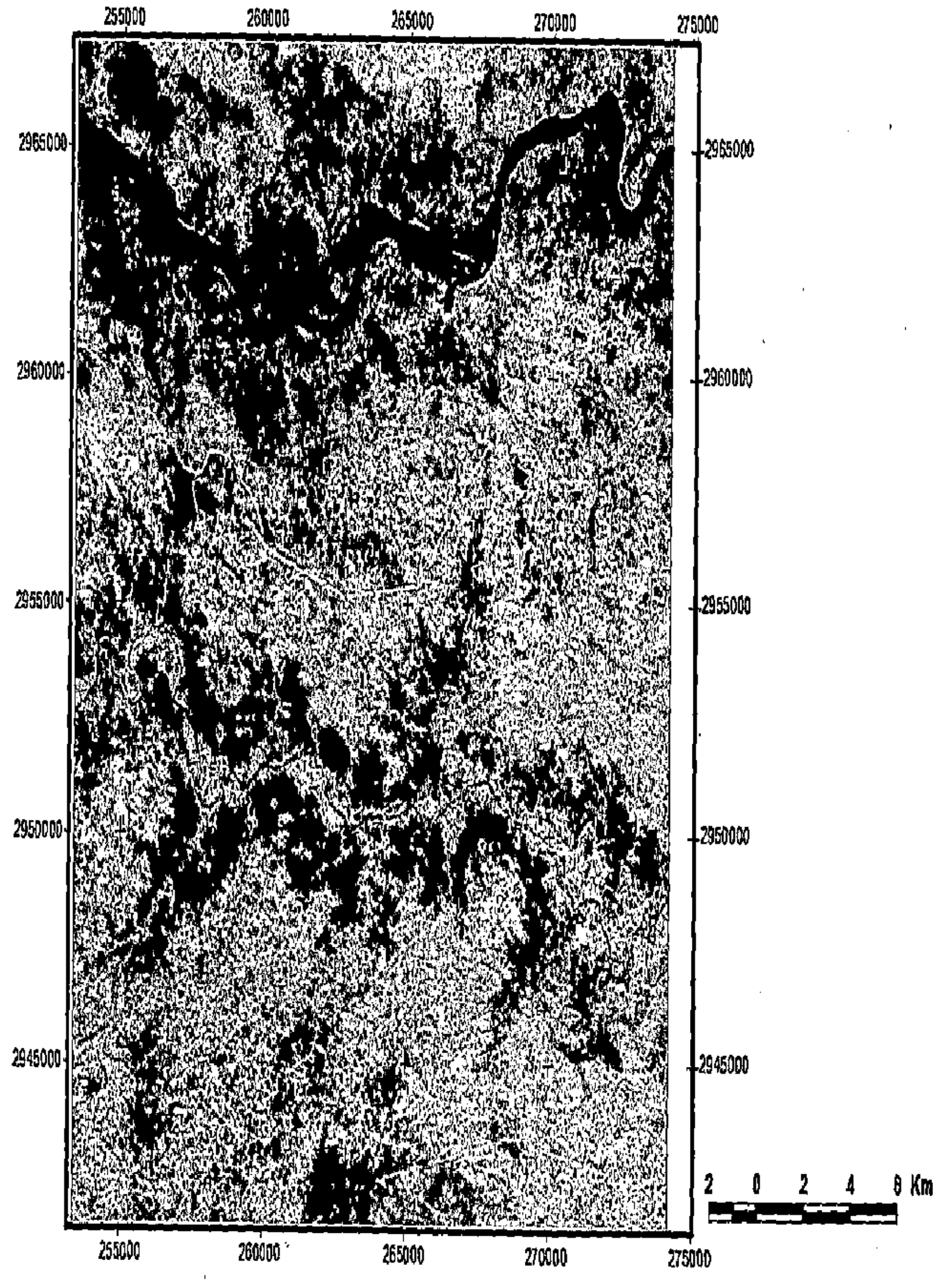


Fig.3.5: Anomaly Detection Image of the Study Area

3.6. Remote Sensing and GIS Softwares used in the Study

Remote sensing and GIS are closely related to one another and with the advancement of technologies in both the field better compatibility have been achieved for better results. GIS is specialized computer program which is designed to analyze spatially referenced data provided by remote sensing systems. Image processing software can be use to extract useful information from the images and GIS help to correlate the extracted information with the spatial and non-spatial data.

3.6.1. SAGA

System Automated Geospatial Analyst (SAGA) is open source software which was used for the processing of elevation data. The cropped tile of ASTER (30m) elevation data saved as GeoTiff file format was imported in SAGA 2.0.3 version. The void filled data was processed for sink removal using Terrain Analysis/Preprocessing/Sink Removal Module. Study area from the ASTER tile was clipped using the shape file created in Arc GIS software using Shape/Grid/Clip gird with Polygon tool and colour coded elevation model was exported as ESRI Arc/Info/Grid in ASCII file format. Sub-watershed boundaries of the study area clipped from ASTER data were delineated using Terrain Analysis/Hydrology/Catchment Area module and saved as ASCII file format. This file was further imported in Arc MAP 9.3 interface for digitizing the boundary of sub-watersheds and creating shape file.

3.6.2. ERDAS IMAGINE

Erdas imagine is remote sensing software used for its raster graphic editor capability. It is used for geospatial application for preparation, display and enhancement of digital images for mapping use in Geographic Information System (GIS). In present study ERDAS IMAGINE is used for georectification, preprocessing and digital image processing of satellite images.

3.6.3. ArcGIS

ArcGIS is complete GIS software for analysis, computation and visualization purpose. Various version of the software have been used at different stages of research according to requirement. Initially beginner version Arc View 3.2 (a) version was used for digitization of various maps obtain from Survey of India, Geological Survey of India (GSI), Indian Institute of Remote Sensing (IIRS) and from literature review. Variables for morphometric parameters were obtained by digitizing georectified toposheet and traced drainage map from LISS-III image and shape files. Excel file of drainage parameters calculated manually was linked with attribute table of shape file of various sub-watersheds in ArcMAP-9.3 interface of ArcGIS-9 version and maps for these parameters were prepared in layout window. Slope and Elevation map was prepared in ArcGIS-10 version under Arc Info license by importing ASCII file from SAGA software. Spatial Analyst extension of ArcMAP-10 interface was used for calculating elevation values and preparing slope map and elevation map. Overlay image for ravine land for change detection is prepared to get a better understanding of pattern of ravines development.

3.7. Soil analysis

Soil samples were collected from valley walls of Chambal and Kunwari river and from bore hole at varying depth with the help of auger for analysis. For soil sampling the study area is divided into grid in a regular pattern and samples were collected from accessible areas. Each sample is analyzed separately to determine the variability in soil property. This information is entered in the GIS system to prepare soil map. Collected samples were dried by spreading the soil in clean, warm and dry area for 2-3 days. The soil has been classified and coded according to the standards of National (Natural) Resources Information System (2000) of India.

3.7.1. Soil pH

pH of soil is the measure of acidity or alkalinity of soil. It is an important property which determines the solubility of various compound, the relative exchange capacity and activity of micro-organism. pH of soil solution highly depend upon the soil:water ratio which is commonly taken as 1:5. pH meter equipped with calomel electrode was used for measuring the pH of soil.

3.7.2. Electronic Conductivity (EC)

EC of soil is used to estimate the level of soluble salt or soil salinity. For measuring electronic conductivity, suspension of soil: water ratio of 1:5 is prepared by aerated distilled water. The suspension is mechanically shaken for an hour and allowed to settle. The EC is measured with the help of conductivity meter by directly dipping the cell into the suspension.

3.7.3. Organic Matter

Organic matter helps in development of proper soil structure. Organic matter in the soil is determined by digesting the samples with excess potassium dichromate solution and sulphuric acid. The residual unutilized dichromate is then titrated with ferrous ammonium sulphate.

3.7.4. Analysis of K, Ca, Mg and Na

EDTA method is used to extract exchangeable Ca and Mg from the soil at 8.5 pH, whereas Na and K was determined using flame photometer.

3.7.5. Cation Exchange Capacity (CEC)

CEC is inherent property of soil that determines the capacity of soil to hold exchangeable cation and is the sum of exchangeable calcium, magnesium, potassium and sodium in soil. Soil with higher clay fraction and organic matter has higher CEC and is less susceptible to leaching of cation from soil and availability of nutrient for plant. If a soil has a large cation exchange capacity and is satisfied by cations such as calcium, magnesium, potassium and sodium a large quantity of hydrogen is required to appreciably change the pH and hence the chemical and physical properties. The relative degree of weathering of soil can also be inferred from the CEC. CEC is expressed in terms of either milliequivalents of adsorbed cations per one-hundred grams soil (me/100g) or centimoles of charge per kilogram (cmol (+)/kg) and is calculated by summing up basic elements such as potassium, magnesium, sodium and calcium.

3.7.6. Exchangeable Sodium Percentage (ESP)

In sodic soil the deflocculating is due to presence of excessive amount of exchangable sodium, which causes soil aggregates and disperses their constituents into individual soil particle. Poor soil structure results into formation of surface soil crusts or the setting of soil into large blocks on drying which will ultimately be susceptible to erosive soil loss during intense rainfall or irrigation cycles via rill and gully erosion. The exchangeable sodium percentage (ESP) is calculated as follows:

$$ESP = \text{Exchangeable } \{(Na)/(Ca + Mg + K + Na)\} \times 100$$

3.7.7. Particle Size Analysis

Soil texture is based on the relative proportion of the various ultimate soil particles, sand particle (>=0.05mm) extracted by sieving method. For silt and clay (<= 0.05mm) fraction sedimentation method based on Stroke's law is used to extract silt and clay distribution. After the sedimentation process the amount of soil lies in suspension is directly determined by hydrometer reading.

CHAPTER – IV

Morphometric Analysis

Morphometric Analysis

4.1. General Statement

The drainage basin or watershed is the fundamental unit in geomorphology within which the relations between landforms and process that modify them is studied. It is a natural laboratory of hydrology which can be defined as the area that drains the entire precipitation into a particular stream outlet. Morphometric analysis of drainage basin and channel network plays a vital role to understand the hydrogeological behavior of drainage basin. Morphometric studies in the field of hydrology were first initiated by Horton, (1932) and then modified by Strahler, (1950). Drainage basin morphometric parameters like linear, aerial, gradient of channel network and contributing ground slopes can be used to describe the basin characteristics. These parameters have been used in various geomorphological studies, surface and sub-surface hydrology, such as flood characteristics, sediment yield, and evolution of basin morphology (Jolly, 1982, Ogunkoya, et al., 1984; Aryadike and Phil-Eze, 1989). Morphometric descriptors represent relatively simple approaches to describe basin processes and to compare basin characteristics (Mesa, 2006) that enable an enhanced understanding of the geomorphic history of a drainage basin (Strahler, 1964).

Morphometry is the measurement and mathematical analysis of the configuration of the earth's surface, shape and dimension of its landforms (Agarwal, 1998; Obi Reddy, et al., 2002). The study of basin morphometry attempts to relate basin and stream network geometries to the transmission of water and sediment through the basin. The quantitative analysis of drainage system is an important aspect of characterization of watersheds. The size of a drainage basin influences the amount of water yield, since the length, shape and relief affect the rate at which water is discharged from the basin and total yield of sediments. However, properties of the stream networks are very important to study the landform making processes and to understand the sub surface conditions.

The relationship between various drainage parameters has been well recognized by Horton, 1945; Strahler, 1957; Melton, 1959; Pakhmode, et al., 2003 and Gangalakunta, et al., 2004. Further, the quantitative hydrogeomorphic analysis of drainage basin introduced by Langbein, (1947) was adopted by various workers, viz; Golding, and Low, 1950; Strahler, 1945, 1950, 1952a, 1954, 1957 and 1958; Schumm, 1956 and Coats, 1958. Geographical Information System (GIS) techniques in conjugation with remotely sensed data are successfully used for assessing various terrain and morphometric parameters of the drainage basins and watersheds, as they provide a favorable environment and a powerful tool for the manipulation and analysis of spatial information. Recently many workers using remote sensing data and data generated using GIS on morphometric parameters, have concluded that remote sensing has emerged as a powerful tool in analyzing the drainage morphometry (Srivastava, and Mitra, 1995; Agarwal, 1998; Nag, 1998; Das, and Mukherjee, 2005).

The development of drainage pattern gives important information about the surface as well as sub-surface condition of the area, either the streams follow the pre defined path formed by various natural or human influences or cut their way through the soil surface forming definite pattern. Drainage map (Fig 4.1) and splitted drainage map (Fig 4.2) were prepared in order to understand various drainage characteristics. Mathematical equations used to calculate various morphometric parameters are given in Table-4.1.Morphometric maps were prepared in GIS environment and detailed morphometric study is carried out and discussed as:

1. Linear Aspects of the Drainage Network
2. Areal Aspects of the Drainage Network
3. Relief aspects of the Drainage Network

4.2. Linear aspects of the drainage network

4.2.1. Stream Segments, and Stream Order (Nu)

The first attribute to be quantified in morphometric analysis is the hierarchy of stream segments. In this system, channel segments were ordered numerically from a stream's head waters to a point somewhere down stream. This is a section of stream channel between two channel junctions or "fingertip" tributaries, between a junction and upstream termination of a channel. It is a fundamental property of stream networks since it is related to the relative discharge of a channel segment.

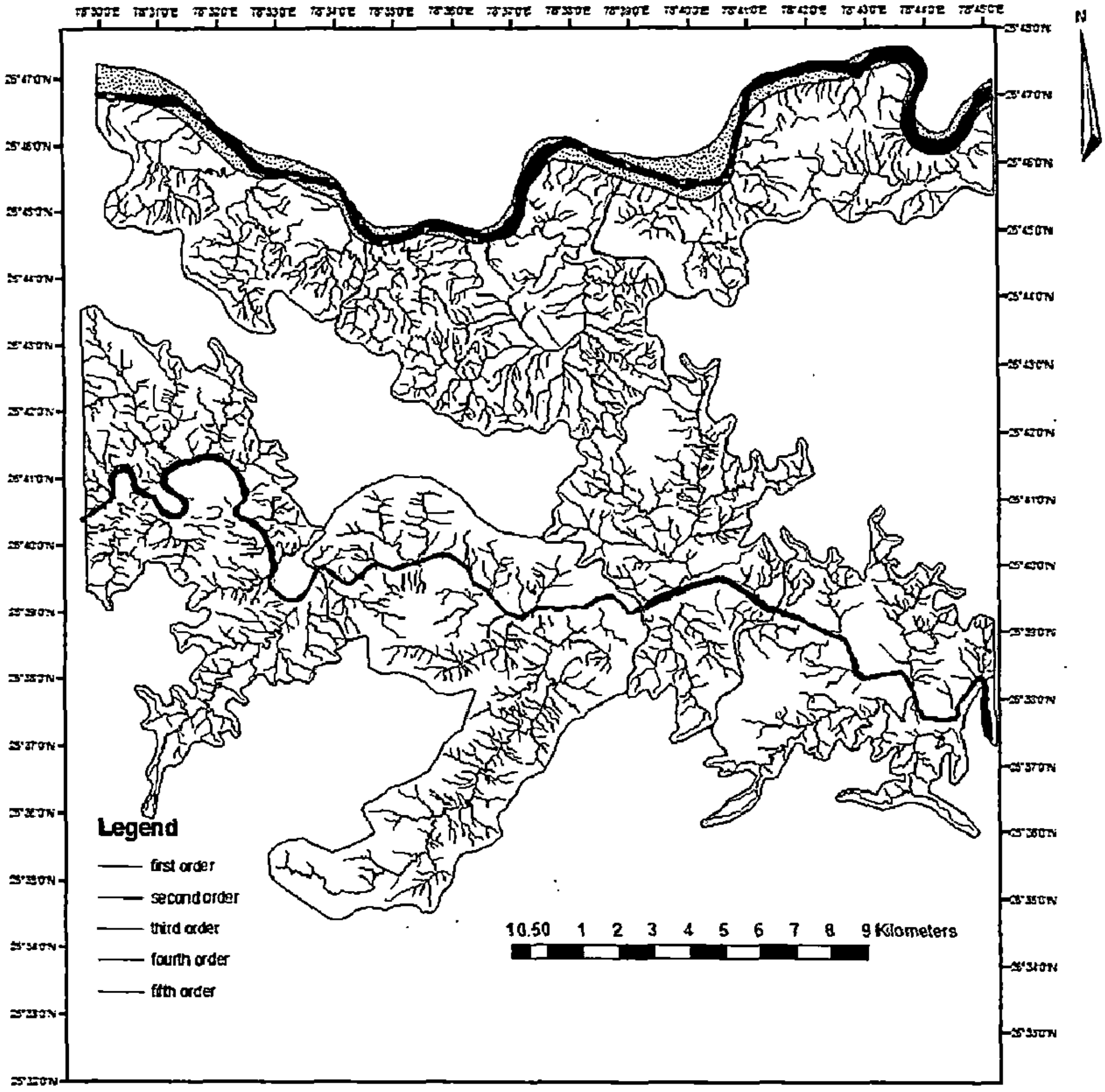


Fig.4.1: Drainage Map of the Study Area

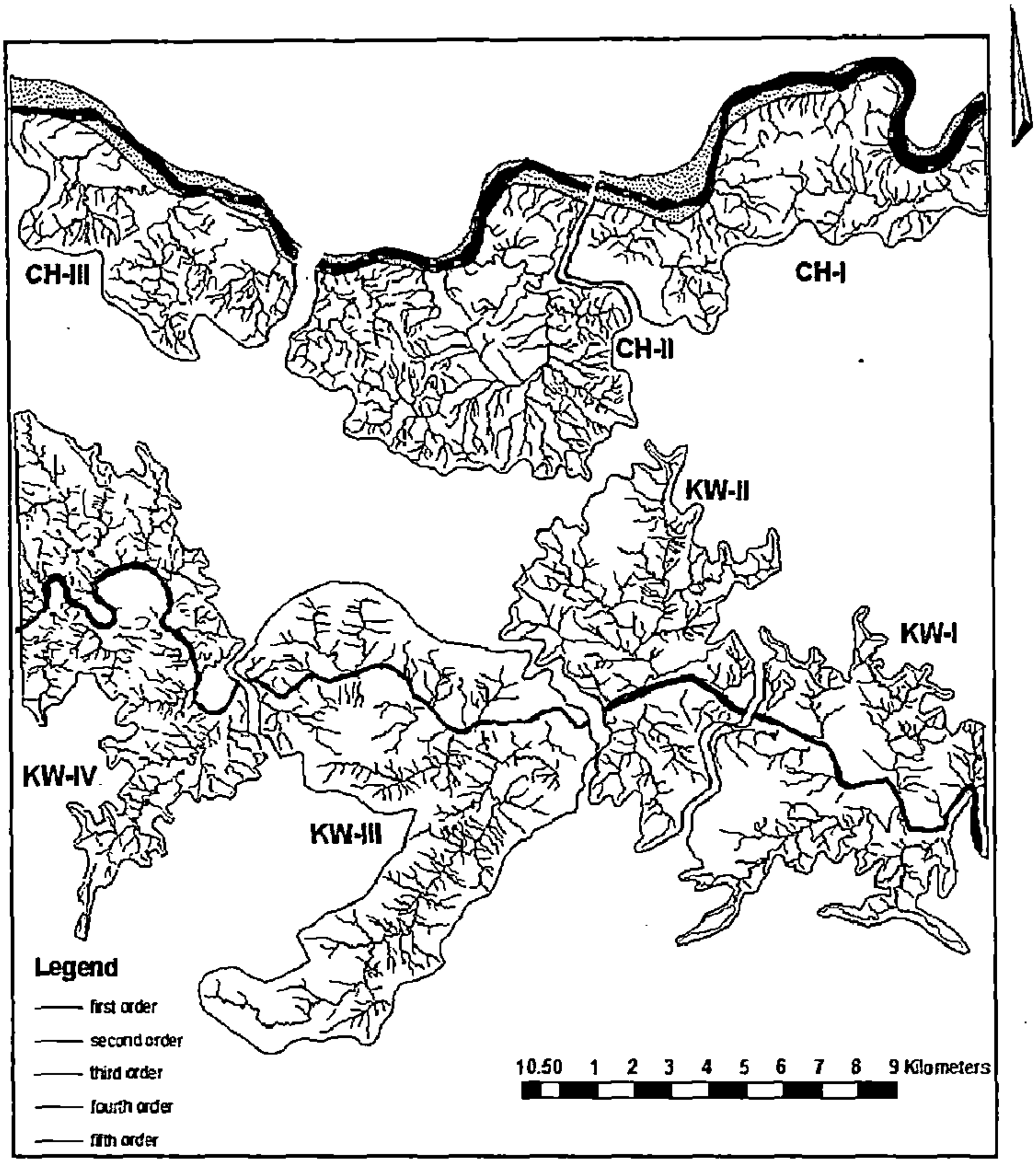


Fig.4.2: Split Drainage Map of the Study Area

Table-4.1: Morphometric Parameters used in Present Study

	Morphometric Parameters	Formula/Definition	References
1.	Stream order	Hierarchical Rank	Strahler (1952,b)
2.	Bifurcation Ratio (Rb)	Rb = Nu / Nu+1	Schumm, 1956)
3.	Mean Bifurcation Ratio (Rbm)	Rbm = Average of bifurcation ratios of all orders	Strahler (1957)
4.	Stream Length (Lu)	Length of the Stream (km)	Horton (1945)
5.	Mean Stream Length (Lsm)	Lsm = Lu / Nu, km	Strahler (1964)
6.	Stream Length Ratio	SLR=Lu/Lu-1	Horton (1945)
7.	Elongation Ratio (Re)	Re= $\sqrt{}$Au/π / Lb	Schumm (1956)
8.	Circularity Ratio (Rc)	Rc = $4\pi Au/P^2$	Miller (1953)
9.	Form Factor (Rf)	Rf = Au / Lb^2	Horton (1932)
10.	Drainage Density (Dd)	Dd= $\sum$Lu /Au) km/km^2	Horton (1932)
11.	Channel of Constant Maintenance (C)	C=1/D	Schumm, 1956
12.	Stream Frequency (Fs)	Fs = $\sum$ Nu /Au	Horton (1932)
13.	Drainage Texture(Dt)	Dt = $\sum$ Nu/P	Horton (1945)
14.	Infiltration Number (Ig)	D × Fs	Horton (1945)
15.	Length of Over Land Flow (Lg)	Lg = 1/ D×2 Km	Horton (1945)
16.	Relief Ratio (Rh)	Rh = H / Lbmax	Schumm (1956)
17.	Relative Relief (Rhp)	Rhp = H× (100) / P	Melton, (1957)
18.	Ruggedness Number (HD)	HD= H×Dd	Strahler, (1958)

The most frequently used stream ordering systems given by Strahler, (1957) and Shreve, (1966). Strahler system is used in present work, where a stream segment without any tributary designates a first order segment. A second order segment is formed by joining of two first order segments, a third order segment by joining of two second order segments and so on.

The stream segments in each order were counted and presented in Table 4.2. It is observed that the number of stream segments of any given order is fewer than for the next lower order but more numerous than for the next higher order. This observation verifies the Horton's Law of stream number (1945) i.e. the number of stream segments of each order forms an inverse geometric sequence with order number. The sub-watersheds CH-II, KW-III and KW- IV (Fig.4.2) have more than 250 first order streams which indicate soft lithology of high dissection in these sub-watersheds. CH-II is the only sub-watershed having one Vth order and three IVth order streams while all the other sub-watersheds have two IVth order streams but no Vth order stream, suggest unconsolidated nature of alluvium in CH-II sub-watershed.

4.2.2. Bifurcation Ratio (Rb)

The frequency with which streams of certain order flow into those of next higher order is refer to as bifurcation ratio. It is the ratio of the number of stream of a given order to the number of stream of next higher order (Schumm, 1956). Horton (1945) considered it as index of relief and dissection. The risk factor of flood is indirectly related with the bifurcation ratio (Waugh, 1996). Mathematically Rb can be defined as:

$$Rb = Nu / Nu+1$$

Where,

Nu: Number of stream segments present in the given order.

Nu+1: Number of next higher order stream

It has been found that the bifurcation ratios characteristically range between 3.0 and 5.0 for watersheds in which geology is reasonably homogeneous or geological structure does not disturb the drainage pattern. However the present study shows that sub-watershed KW-III and KW-IV having higher values of Rb,7.5 and 9 respectively

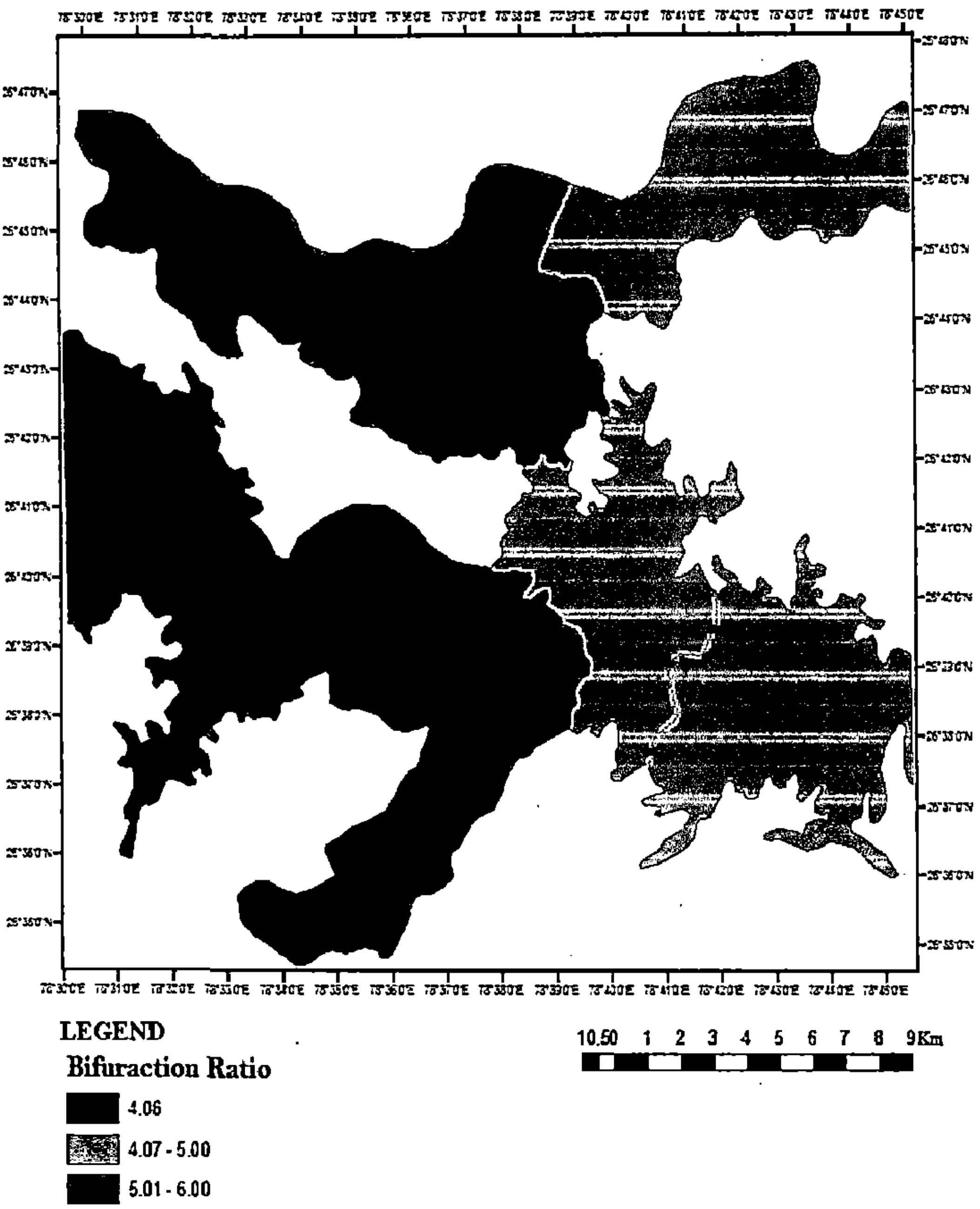


Fig.4.3: Mean Bifurcation Ratio Map

Table-4.2: Stream Number and Bifurcation Ratio

Stream Orders	CH - I		CH - II		CH - III		KW-I		KW-II		KW-III		KW-IV	
	Nu	Rb	Nu	Rb	Nu	Rb	Nu	Rb	Nu	Rb	Nu	Rb	Nu	Rb
I	135	4.2	251	4.04	136	4.25	143	4.2	172	4.3	250	4.46	252	3.5
II	32	3.55	62	3.87	32	4	34	3.7	40	4.44	56	3.73	71	3.9
III	9	4.5	16	5.33	8	4	9	4.5	9	4.5	15	7.5	18	9
IV	2		3	3	2		2		2		2		2	
V			1											

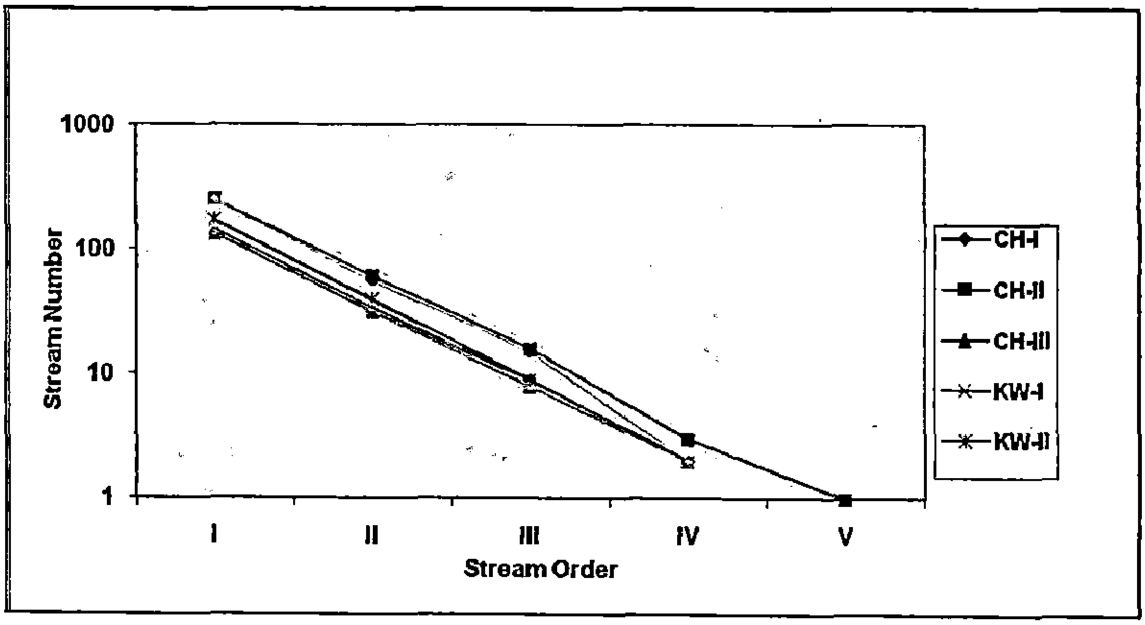


Fig.4.4: Semi log plot of Stream Order Vs Stream Number

indicates that the structures have little control over drainage development in these sub-watersheds. All the other sub-watersheds have values in the range of 3-5 which may be attested the presence of very thick alluvium over the Vindhyan sediment. The variable Rb values in the watersheds of the study area possibly depend upon the drainage basin. The lower values are characteristics of the sub-watershed, suffered less structural disturbances (Strahler, 1964) and the drainage patterns have not been distorted. Further, the low Rb values signify high drainage density in the study area, clearly indicates uniform surficial material where geology is reasonably homogeneous. High Rb values indicate structural control of drainage directions and signify higher average flood potential due to numerous tributary segments, drain into relatively few trunks. A long basin with a high bifurcation ratio results in a hydrograph, yield a low extended peak flow while a round basin with a low bifurcation ratio would yield a sharp peak (Strahler, 1964).The present study show that the mean Rb value ranges between 4.06 and 5.46 (Table 4.3, Fig.4.3) which appear higher than the range expected for dendritic drainage pattern (3.5-4) indicates that the drainage basin has dendritic to sub-dendritic drainage pattern. Semi log plots of Stream order vs Stream numbers have been drawn and a straight line was fitted through these points (Fig.4.4). The slope of these lines gives the bifurcation ratio.

4.2.3. Stream Length (Lu)

It is the length of stream of various orders from their mouth to drainage divide. The stream length has been computed based on the law proposed by Horton (1945). First order streams have maximum total stream length which gradually decreases with higher order streams due to flow of stream from high altitude, change in rock type, moderately steep slope and probable uplift across the watershed (Singh and Singh, 1997, Vittala et al 2004, Chopra et al, 2005). This trend is showed in all the sub-watersheds except sub-watershed CH-III (Table. 4.4).

4.2.4. Mean Stream Length (Lsm)

Mean Stream length is calculated by dividing the total stream length of order 'U' and number of stream of segment of order 'U' using the formulae:

$$Lsm = Lu / Nu$$

Where, Lu: mean stream length of a given order, Nu: number of stream of that order.

Table-4.3: Total Number, Total Stream Length and Mean Bifurcation Ratio of Sub-watersheds

S.No.	Name of Sub-watersheds	$\sum Nu$	$\sum Lu$	Mean Rb
1	CH – I	178	99.82	4.08
2	CH-II	333	180.62	4.06
3	CH-III	178	90.27	4.08
4	KW-I	188	117.05	4.13
5	KW-II	223	126.28	4.41
6	KW-III	323	163.09	5.23
7	KW-IV	343	181.63	5.46

The mean stream length of a channel segment of order 'U' is a dimensional property, revealing the characteristic size of component of drainage network and contributing basin surface (Strahler, 1964). Lsm of any given order is greater than that of lower order and less than that of its next higher order. In the study area the value of mean stream length (Table.4.4 and Fig 4.5) varies from 0.44 - 4.43 km in CH-II sub-watershed, suggest gentle relief and topography of the area.

4.2.5. Stream Length Ratio (SLR)

Stream Length ratio can be defined as the ratio of mean stream length of a given order to mean stream length of next lower order and is determined by the formula:

$$SLR = Lu / Lu\text{-}1$$

Where,

Lu: Mean Stream Length of a given order.

The mean stream length also has important relationship with the surface flow discharge and erosional stage of the basin (Sreedevi et, al, 2009). Horton (1945) law of stream length states that mean stream length segments of each of the successive orders of a basin tends to approximate direct geometric series with streams length increasing towards higher order of streams. From Table 4.4 it is noted that the variable stream length is possibly due to variation in slope and topography of the basin. The sub-watersheds CH-I, CH-III and KW-IV show increasing trend in stream

Mean Stream Length and Stream Length Ratio

CH - II			CH - III			KW - I			KW - II			KW - III			KW - IV		
SL (Km)	MSL (Km)	SLR	SL (Km)	MSL (Km)	SLR	SL (Km)	MSL (Km)	SLR	SL (Km)	MSL (Km)	SLR	SL (Km)	MSL (Km)	SLR	SL (Km)	MSL (Km)	SLR
11.84	0.44	0.60	60.06	0.44	0.63	71.81	0.50	0.49	81.33	0.47	0.30	107.76	0.43	0.41	112.59	0.44	0.54
39.24	0.63	0.40	18.32	0.56	0.39	23.79	0.69	0.60	23.23	0.58	0.71	37.82	0.67	0.32	40.00	0.56	0.47
17.84	1.11	0.45	7.27	0.90	0.30	14.31	1.59	0.33	16.62	1.84	0.28	12.40	0.82	0.35	18.84	1.04	0.35
7.27	2.42	0.35	7.73	2.31		7.14	3.57		5.10	2.55		5.11	2.55		10.20	5.1	
4.43	4.43																

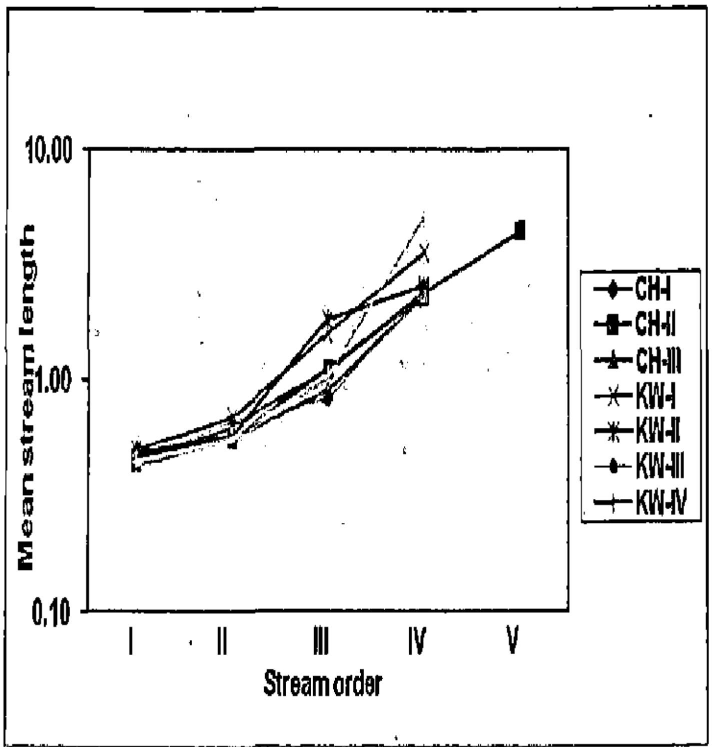


Fig.4.5: Semi Log Plot of Stream Order and Mean Stream Length

length ratio from lower to higher order, indicating mature geomorphic stage of development, whereas all other sub-watersheds depict variable values of stream length suggest late youth stage of geomorphic development.

4.3. Aerial Aspects of the Drainage Network

4.3.1. Basin Area

Delineation of drainage basin is carried out manually using topographic information. However, wide spread availability of elevation data in digital format has bolstered the development of automated tools that can be used to delineate drainage basin and their associated stream network. In the present study sub-watersheds are delineated from the ASTER 30m elevation data through automated process. Total area of the watershed is 183 km^2. Among all the sub-watersheds, maximum drainage area is covered by the sub watershed CH–I, whereas minimum drainage area is covered by sub-watershed KW-IV (Table.4.5).

4.3.2. Basin Shape (Bs)

Drainage basin shape is defined as shape or outline of a drainage basin, projected upon the horizontal datum plane of a map. The shape of the basin is used to determine discharge characteristics of streams and may considerably affect stream flow hydrograph and peak flow. Horton (1945) described the outline of a normal drainage basin as a pear shape ovoid. The various parameters which are used to define the shape of the basin include Elongation Ratio (Re), Form Factor (Rf) and Circularity Ratio (Rc).

4.3.2.1. Elongation Ratio (Re)

Schumm, (1956) defined elongation ratio as the ratio of diameter of a circle of the same area as the basin to the maximum basin length. The elongation ratio ranges between 0.6 and 1.0 over a wide variety of climate and geographical types. The elongation ratio near to 1 is typical in the region of very low relief, whereas values between of 0.6 and 0.8 are generally associated with high relief and steep ground slope. High Re value indicates that the area has high infiltration capacity and low run off while low values are susceptible to high erosion and sedimentation load. These

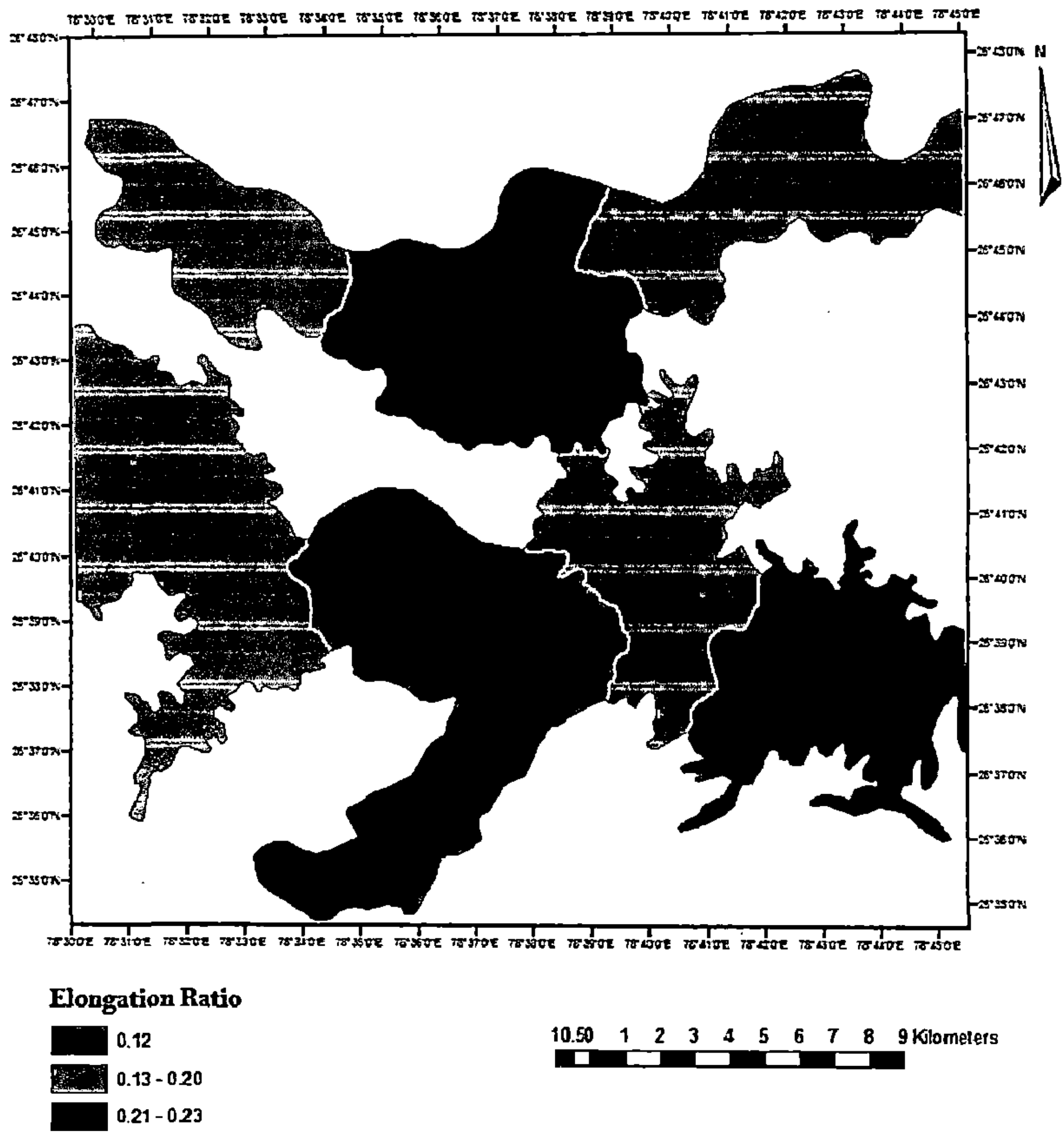


Fig.4.6: Elongation Ratio Map

values are further categorized as circular (>0.9), oval (0.9-0.8) and less elongated (<0.7). The sub-watershed of the study area characterized by low elongation ratios (0.12 to 0.23) having strong relief, steep ground slope and high erosion and sedimentation with less elongated shape. Elongation ratio may be determined by using formulae:

$$Re = \frac{\sqrt{Au\pi}}{Lb}$$

Where,

Au: Basin Area (Sq km)

Lb: Maximum Basin Length

Further, low values of elongation in the study area indicate low infiltration and high runoff, susceptible to gullied and ravine erosion. The low value (0.12) of Re determined in sub-watershed KW-III clearly indicated that the sub-watershed is having steep slope, high relief, and elongated shape (Fig. 4.6) tends to be affected by soil erosion mainly by running water.

4.3.2.2. Circularity Ratio (Rc)

Circulatory ratio is expressed as the ratio of basin area (Au) to the area of a circle having the same perimeter (P) as the basin (Strahler, 1964) and can be determined by the formulae:

$$Rc = \frac{4\pi Au}{P^2}$$

Where,

Au: Basin Area (Sq km)

P: Perimeter of the basin (km)

Circularity Ratio is dimensionless and expresses the degree of circularity of the basin. It is influenced by length and frequency of streams, geological structure, landuse/landcover cover, climate, relief and slope of the basin (Vittal, et al., 2004). Horton (1945) has given the values of circularity ratio from 0.6 to 0.7 for the homogenous geological material to preserve geometric symmetry. In the study area circularity ratio ranges from 0.14 to 0.50 (Table.4.5). Sub-watershed CH-II having value 0.50 appear to be more or less circular (Fig.4.7) while all the other sub-watersheds are elongated in shape where KW-I being the most elongated.

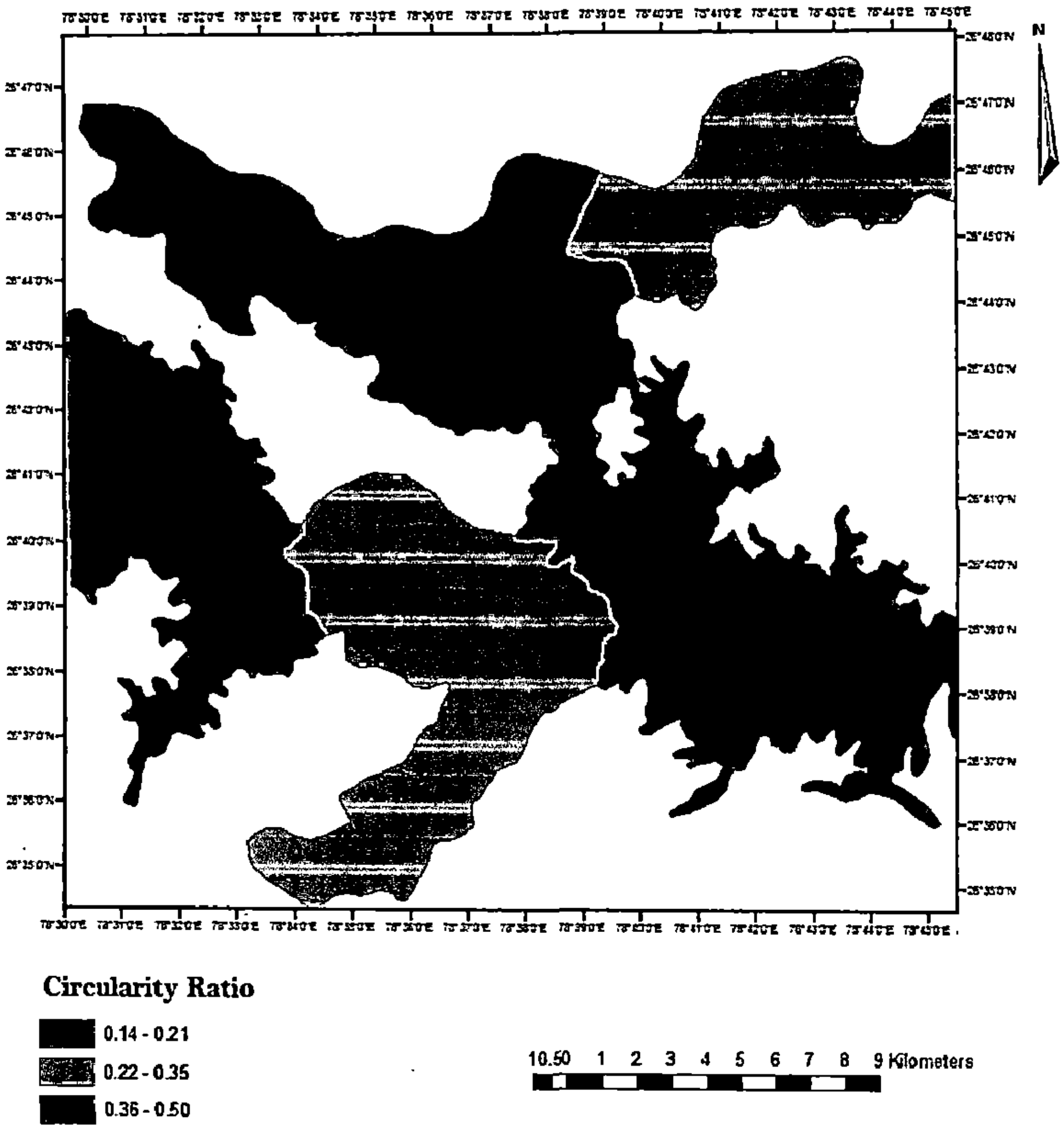


Fig. 4.7: Circularity Ratio Map

4.3.2.3. Form Factor (Rf)

Horton (1932) proposed this parameter to predict the flow intensity of a basin having a definite area. It is defined as the ratio of basin area to the square of basin length and can be determined by the formula:

$$Rf = A / Lb^2$$

Where,

Au: Basin Area (Sq km)

Lb: Maximum Basin Length

Rudraiah, et al., (2008) suggested that a perfectly circular basin have form factor value >0.78. However, low form factor value in the area of interest ranging from 0.31 in sub-watershed KW-II to 0.53 in KW-I, suggest that all the sub-watershed falls in the elongated basin category. These sub-watersheds tends to be elongated with low form factor values, indicates that the basin have a flatter peak of flow for longer duration. However, flood flow for such basins is easier to manage. Sub watershed KW-II has low value of shape factor (Fig.4.8) and hence flood flow is easily managed. Further, values of sub watershed CH-III, KW-II and KW-IV fall between 0.31-0.35 (Fig.4.9) shows that these sub-watersheds are more elongated.

4.3.3. Drainage Density (Dd)

Drainage density expresses the closeness of spacing of channels introduced by Horton (1932) and is an important indicator of the linear scale of land form element in stream eroded topography. It is define as the total length of stream of all order per unit area and is a measure of how well or how poorly a watershed is drained by streams channels. It provides numerical measurement of landscape dissection and runoff potential. The drainage density can be determined by the formulae:

$$Dd = \sum Lu / Au$$

Where,

$\sum Lu$: Total Channel segments length cumulated from each other (Km)

Au: Basin Area (Sq km)

Table-4.5: Shape Parameters of different Sub-watersheds

S.No	Name of Sub-watersheds	Basin Area (km^2)	Perimeter (km)	Max Basin Length (km)	Elongation Ratio (Re)	Circularity Ratio (Rc)	Form Factor (Rf)
1	CH – I	130.50	35.57	8.95	0.20	0.31	0.39
2	CH-II	116.50	33.28	9.47	0.22	0.50	0.49
3	CH-III	30.00	25.23	8.65	0.18	0.48	0.32
4	KW-I	39.61	58.7	8.61	0.23	0.14	0.53
5	KW-II	34.89	49.07	10.49	0.18	0.18	0.31
6	KW-III	62.61	47.05	12.64	0.12	0.35	0.39
7	KW-IV	52.02	55.56	12.14	0.19	0.21	0.35

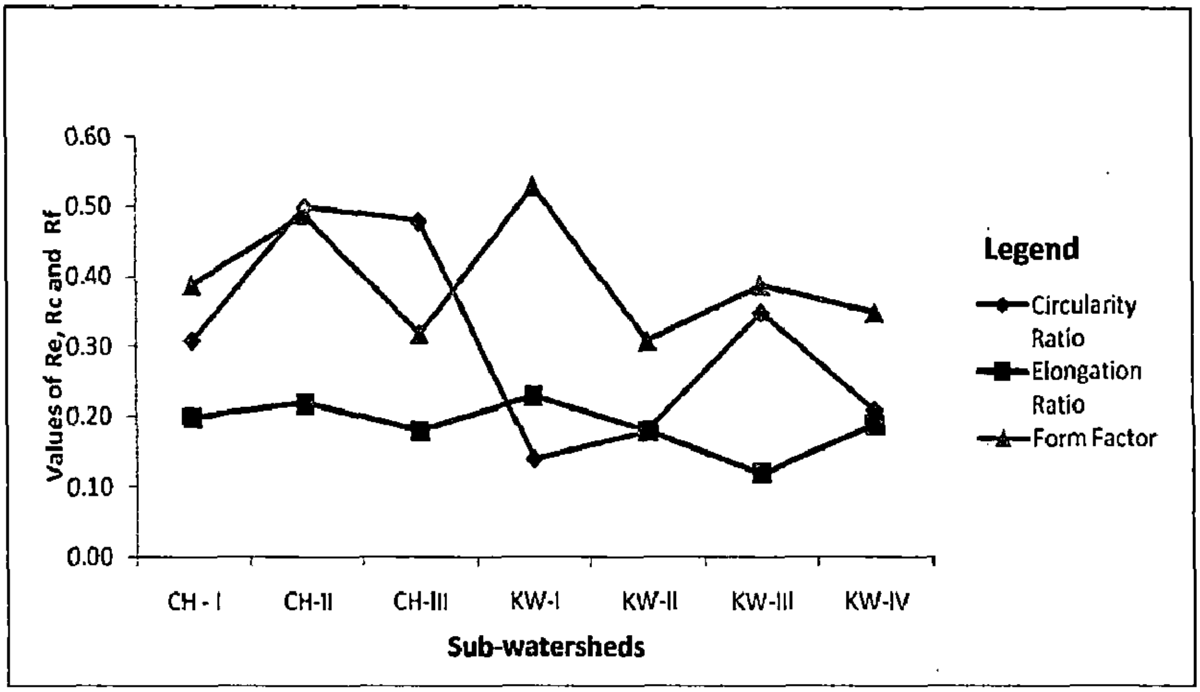


Fig.4.8: Graphical Representations of Shape Parameters of Different Sub-watersheds

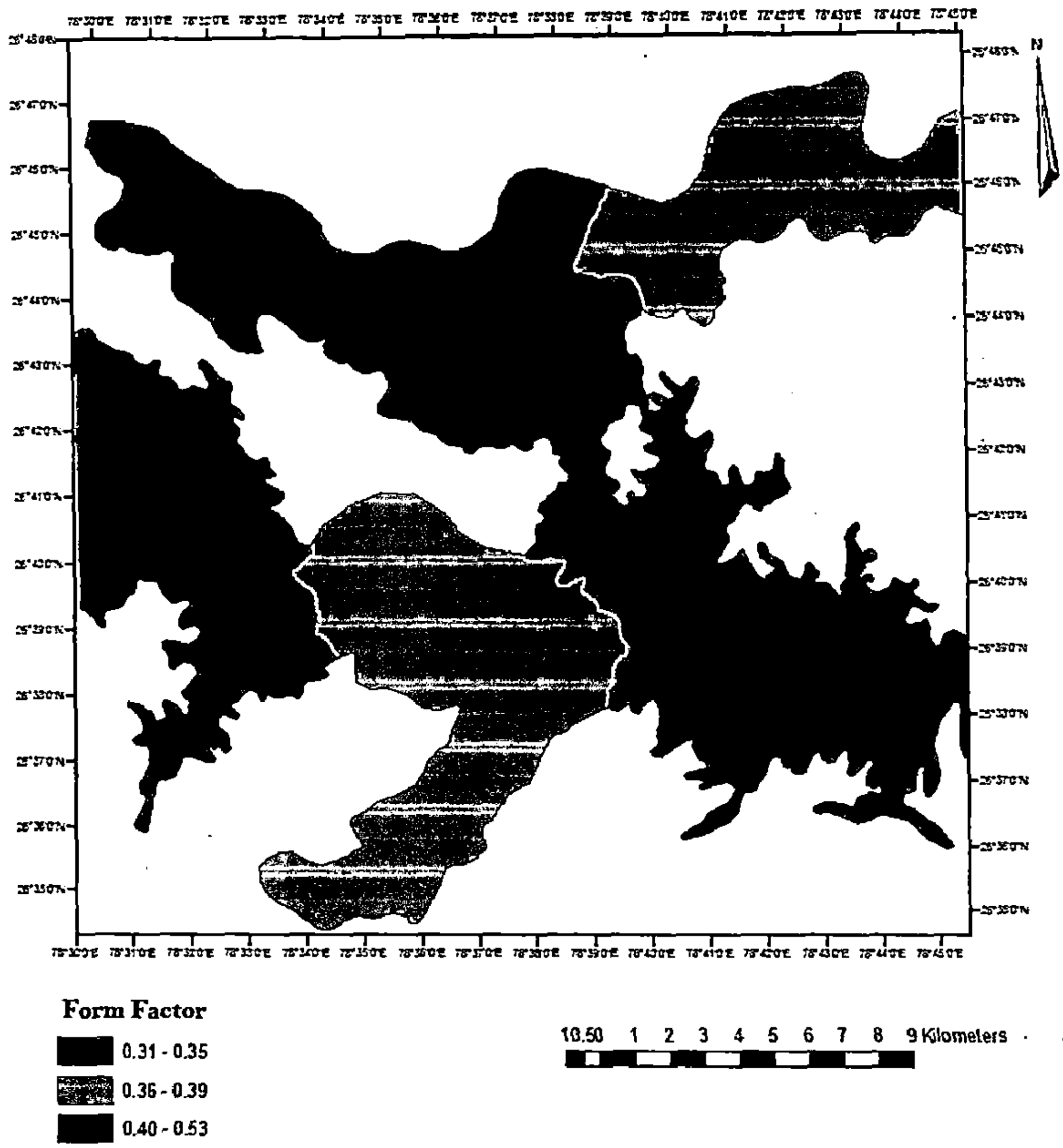


Fig.4.9: Form Factor Map

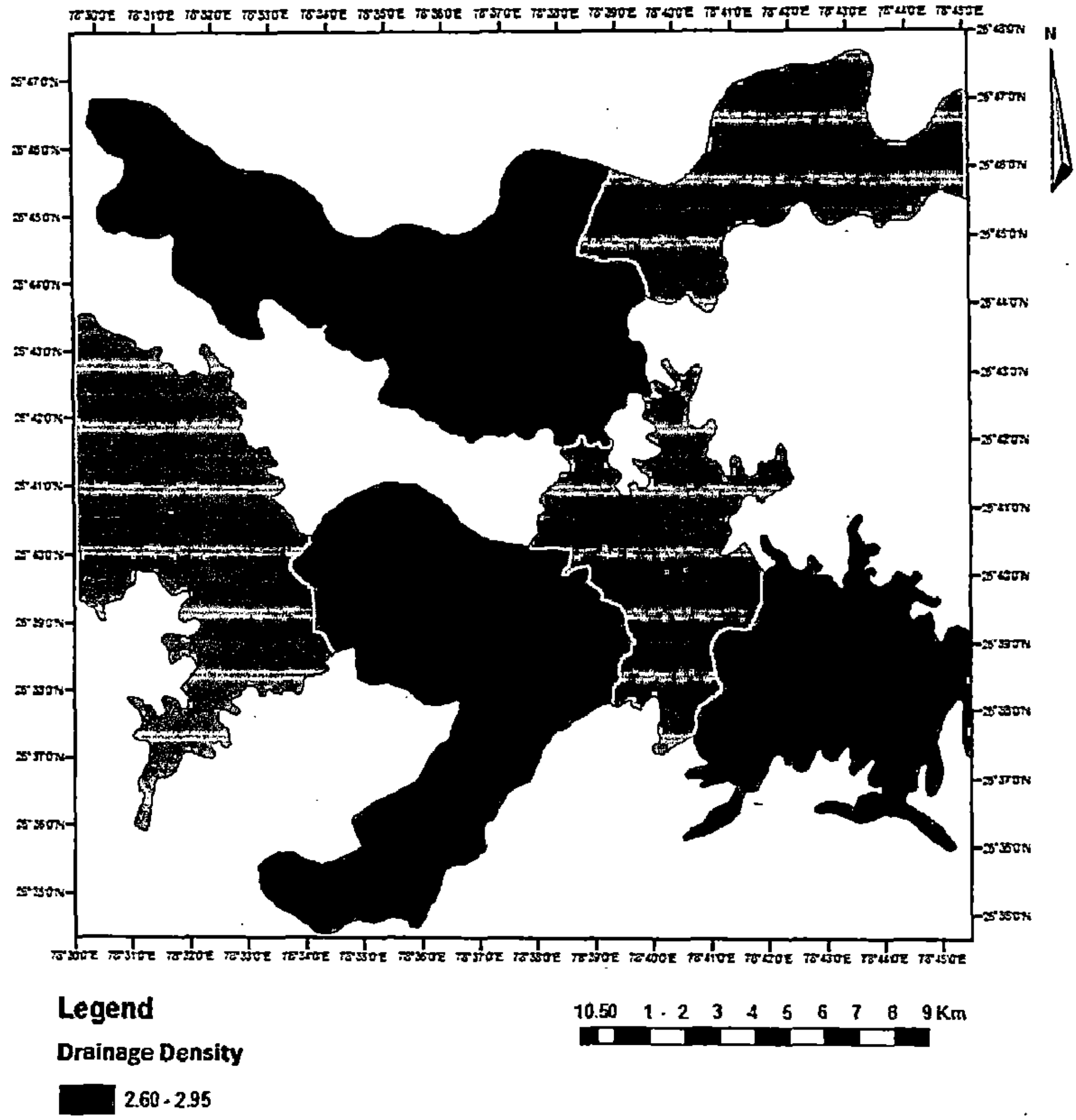


Fig. 4.10: Drainage Density Map

High drainage densities usually reduce the discharge in any single stream, more evenly distributing runoff and accelerating into secondary and tertiary streams. Areas with high drainage density signify that water goes to drain a primary stream and same time arrives to a secondary stream. Dynowska, (1976) demonstrated that drainage densities are higher in region where streams are highly loaded with alluvium. Bratsev, (1964) showed that drainage density is high in plains than in mountain since stream length in plain is more due to meandering and sinuosity. The inverse relationship between drainage density and base flow is demonstrated by Carlstön, (1963) appear to be related with permeability of rock type. The large quantity of water moves on the surface of the drainage system, indicate the higher drainage density which in turn means the base flow is low (Bell, 2003). In general low drainage density is favored in the regions of highly permeable subsoil under dense vegetative cover and low relief. The low drainage density is also indicative of relatively long overland flow of surface water. High drainage density is favored in regions of weak or impermeable subsurface materials, sparse vegetation and high relief (Chow 1964).Langbein, (1947) recognized the significance of drainage density as a factor determining the time of travel by water and suggest that drainage density varying between 0.55 and 2.09 km/km2 in humid region with an average density of 1.03 km/km^2. However, drainage density is maximum in semi-arid region (Langbein, and Schumm, 1958 and Gregorgy, and Gardiner, 1975).

The drainage density in the study area varies from 2.60 to 4.36 km/km^2 suggest that the area is semi-arid plain with high alluvium loaded stream due to impermeability of sub-surface lithology. High value of drainage density is found in sub-watershed CH-II and CH-III while low in sub-watershed KW-III (Fig.4.10).The low values of drainage density indicates the presence of impermeable strata in KW-III sub-watershed.

4.3.4. Channel of Constant Maintenance (C)

The reciprocal of the drainage density is constant of channel maintenance, proposed by Schumm, (1956) signifies how much drainage area is required to maintain a unit length of channel. It is illuminating and presaging the usefulness in sediment-yield to estimate the low values of this constant, i.e., a small area to maintain a given channel, is associated with weak or low-resistance soil, sparse vegetation and hilly terrain.

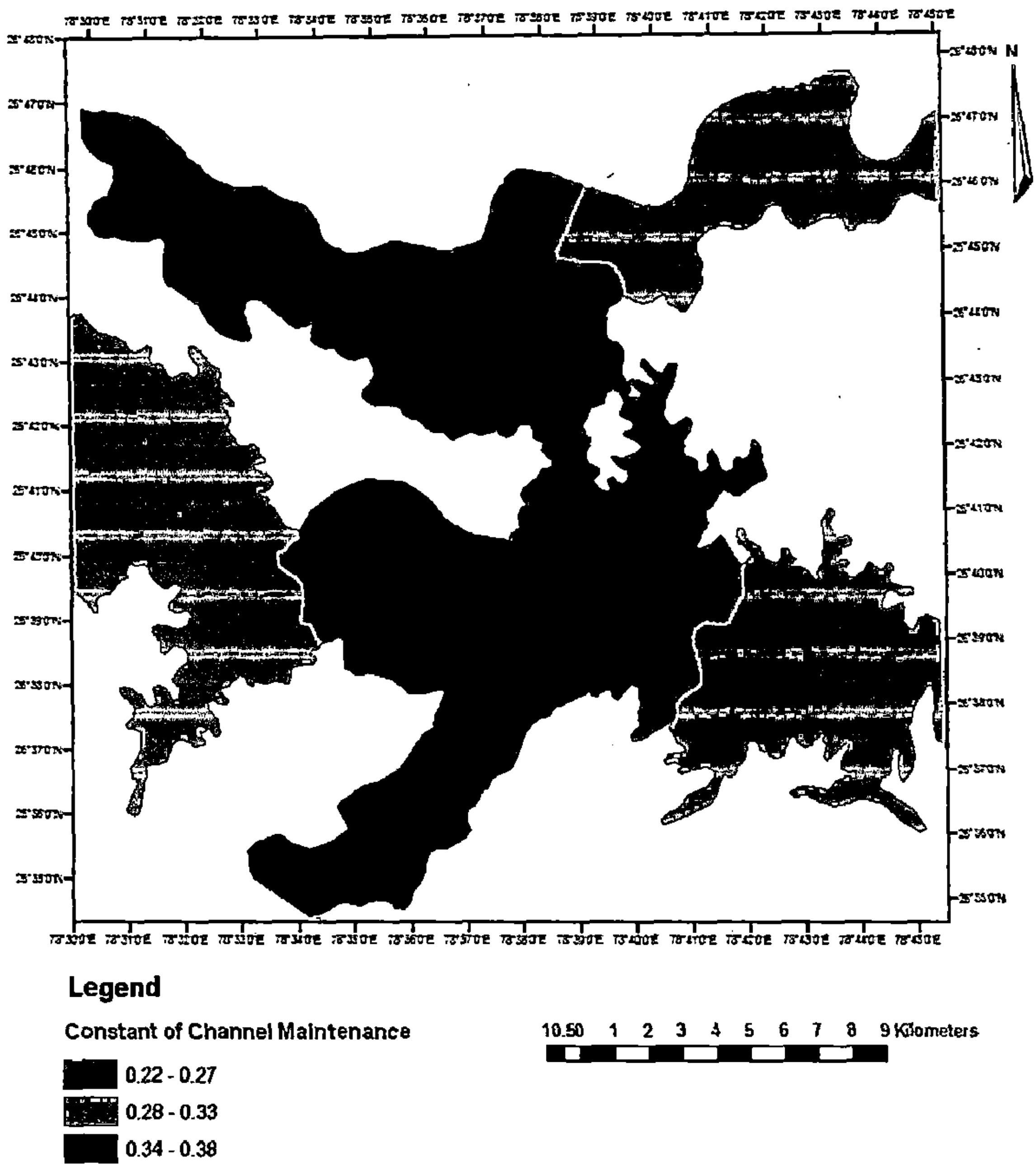


Fig. 4.11: Channel of Constant Maintenance Map

Table-4.6:Drainage Density, Stream Frequency, Constant of Channel Maintenance Length of Overflow, Drainage Texture and Infiltration Number of Sub-watersheds

S.No.	Name of Sub-Watersheds	Drainage Density (Dd)	Stream Frequency (Fs)	Constant of Channel Maintenance (C)	Length of Overland flow (Lg)	Drainage Texture (Rt)	Infiltration Number (If)
1	CH – I	3.17	5.66	0.31	0.15	5.00	15.85
2	CH-II	4	7.47	0.25	0.12	10.00	40.00
3	CH-III	4.36	3.2	0.22	0.11	7.04	30.69
4	KW-I	2.95	4.7	0.33	0.16	5.12	15.10
5	KW-II	3.61	6.39	0.27	0.13	4.50	16.24
6	KW-III	2.6	5.1	0.38	0.19	6.86	17.83
7	KW-IV	3.4	6.5	0.29	0.14	6.17	20.97

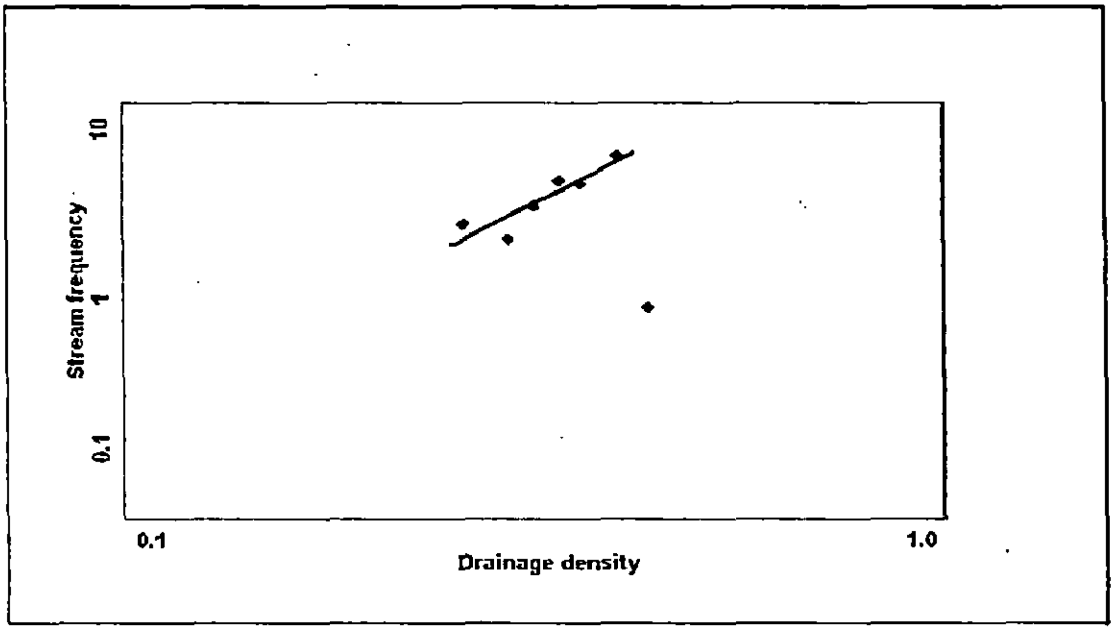


Fig.4.12: Log-Log Plot of Drainage Density and Stream Frequency

Lowest value is found in sub-watershed CH-III and the highest in sub-watershed KW-III (Table-4.6 and Fig.4.11) indicating low resistant soil and undulating terrain in sub-watershed CH-III, and signify high sediment yield in sub-watershed CH-III.

4.3.5. Stream Frequency (Fs)

Horton (1932) defined stream frequency as the number of stream segment per unit area and is given by the formulae:

$$Fs = \sum Nu / A$$

Where,

Nu: Total number of streams in the basin

Au: Basin Area (Sq km)

The high stream frequency values in the sub-watersheds of the area of interest are not corelatable with drainage density (Table-4.6) indicates the possibilities to construct drainage basin having the same drainage density but different stream frequency. High drainage density and low stream frequency in sub-watershed CH-III and positive relation of drainage density and stream frequency in other sub-watershed (Fig. 4.12 and Table 4.6) show high degree of dissection of the landscape and appear due to erodable nature of soil and rock. Further, the variable stream frequency and drainage density, lowest drainage density and high stream frequency in sub-watershed KW-III and lowest value of stream frequency in CH-III (Fig.4.13) indicates disproportionate increase in the length of streams in relation to stream number. Such exception has also been reported in Romanian Quaternary Formations (sand, silt and clay) where stream segment decreases greatly and no longer proportionate with river length (Zavoianu, 1985). Stream length also increases because of the higher sinuosity of streams, resulting in higher drainage density.

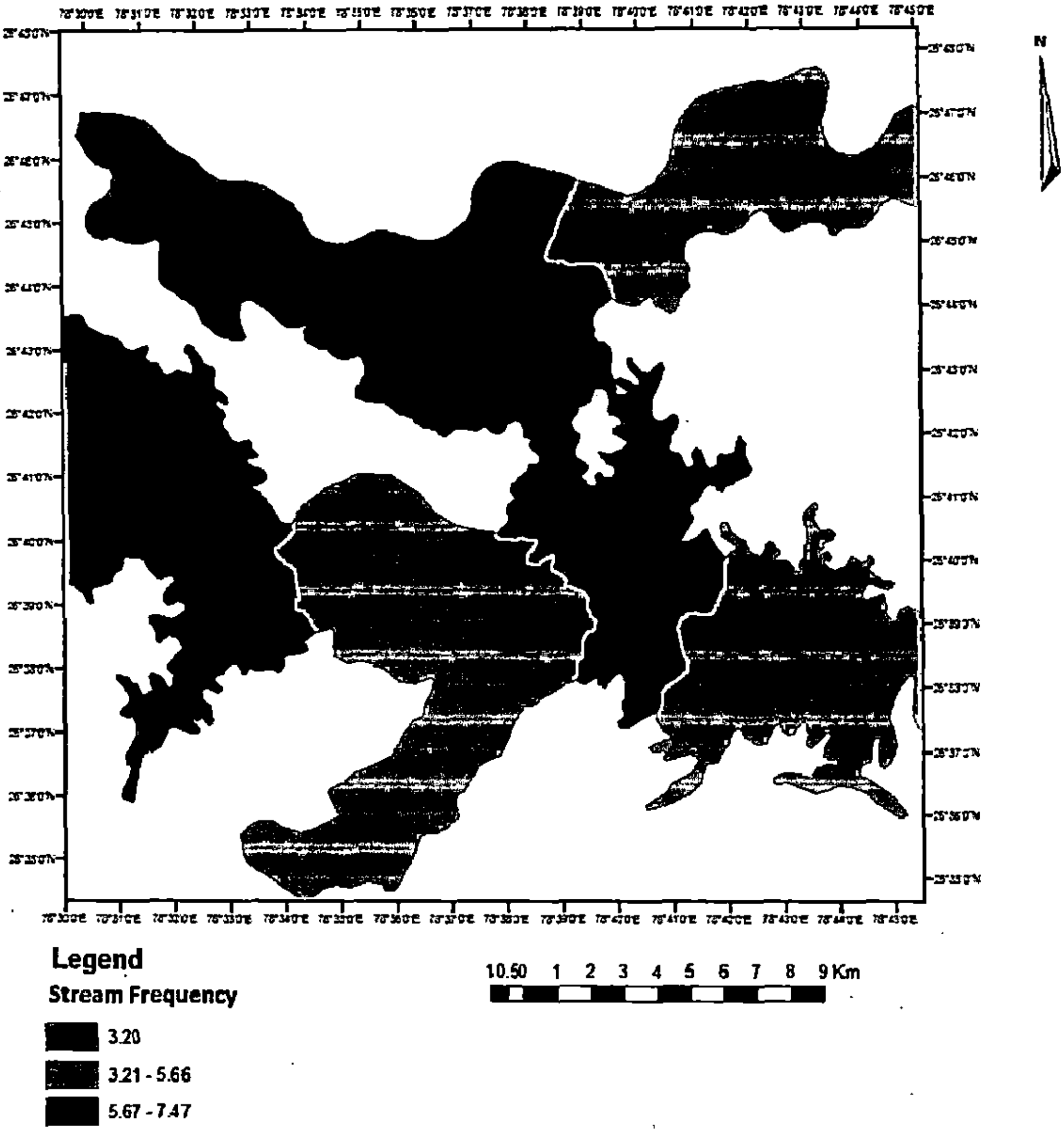


Fig.4.13: Stream Frequency Map

4.3.6. Drainage Texture (Dt)

Horton (1945) described drainage texture is the total number of stream segments of all orders per perimeter. He recognized infiltration capacity as the single important factor which influence drainage texture and includes drainage density and stream frequency. Drainage texture can be determined by the formulae:

$$Dt = \sum Nu/P$$

Where,

$\sum Nu$= total number of streams

P= Perimeter of sub-watershed

Smith (1950) classified drainage texture into five different drainage textures. The Dt less than 2 indicates very coarse, between 2 and 4 is related to coarse, between 4 and 6 is moderate, between 6 and 8 is fine and greater than 8 is very fine drainage texture. Present study indicates that the drainage texture of study area is moderate to very fine (Table-4.6).

Drainage texture classification map (Fig.4.14) show that sub-watersheds KW-I, KW-II and CH-I fall in moderate texture category, while KW-III, KW-IV and CH-III falls in fine and CH-II falls in very fine texture category, indicating impermeable sub-surface, soft and weak surficial lithology. Soft and weak surface unprotected with vegetation and give rise fine texture, whereas massive and resistant rock forms coarse texture. The thick unconsolidated alluvial cover produces moderate to very fine texture of drainage in the study area.

4.3.7. Infiltration Number (If)

Infiltration number plays a significant role in observing the infiltration characters of a basin. It is expressed as the product of the drainage density and stream frequency and can be given as:

$$If = D \times Fs$$

Where,

D: Drainage density

Fs: Stream frequency

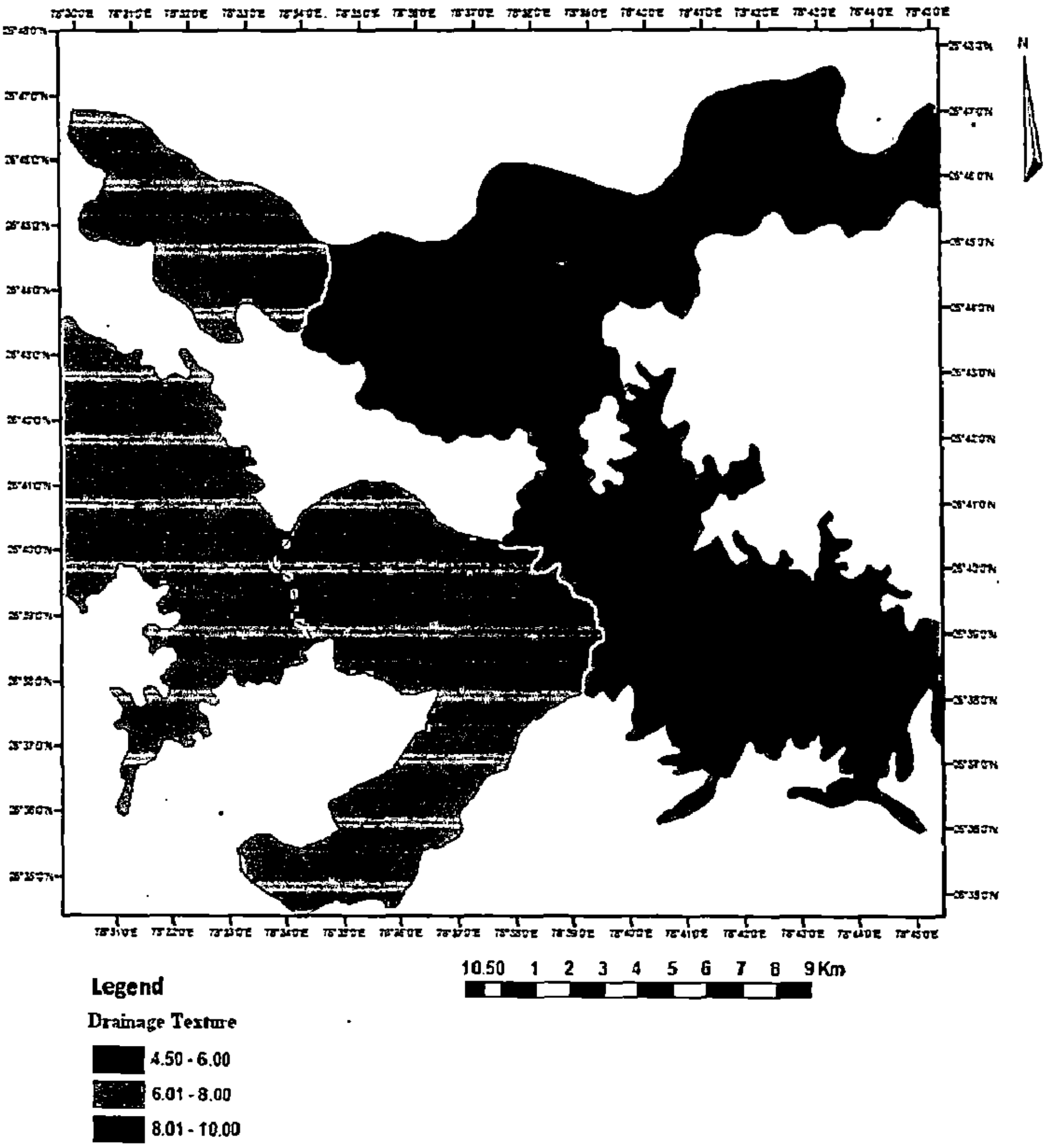


Fig.4.14: Drainage Texture Map

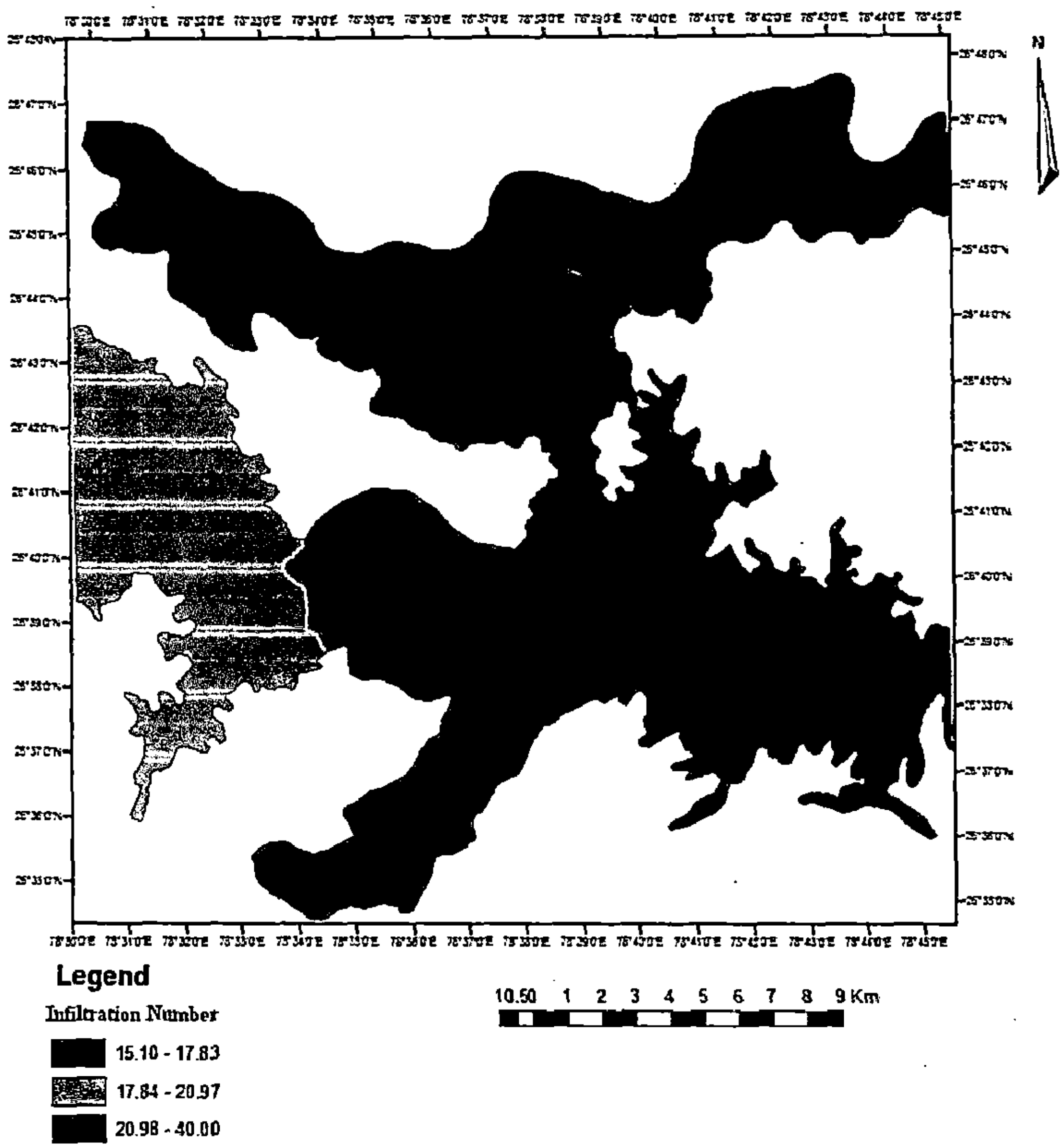


Fig.4.15: Infiltration Number Map

High values of infiltration number in all sub-watersheds indicate low infiltration and high runoff. These values also suggest that the condition of gully erosion may be further aggravated in future due to high runoff potential of the area. All the sub-watersheds have high values of infiltration number where CH-I and CH-II having the highest values (Fig.4.15) and sub-watershed CH-II has high values of drainage density, drainage texture and infiltration number, makes together that this sub- watershed prone to sever soil erosion by water.

4.3.8. Length of Overland Flow (Lg)

Horton (1945) defined length of overland flow as the length of flow path, projected to the horizontal non channel flow from point on the drainage divide to a point on the adjacent stream channel. He further mentioned that the length of overland flow is one of the most important independent variable affecting both hydrologic and physiographic development of drainage basin. The length of overland flow is approximately equal to the half of the reciprocal of drainage density and can be given as:

$$Lg = \frac{1}{2} (Au / Lu)$$

Where,

Au: Basin Area (Sq km)

L: Length of the Basin

Lg is the length of water over the ground before it gets concentrated indefinite stream channels (Horton, 1945). This factor is inversely proportional to the average slope of the channel and is synonymous with the length of sheet flow to a large degree. If the basin is well drained the value of overland flow appears to be short and the surface runoff gets concentrated quickly with high flood peak and correspondingly low flow.

The overland flow is higher in semi-arid region than in humid and humid temperate region due to lack of vegetative cover (Kale and Gupta, 2001) Table-4.6 reveals that Lg is high in all the sub-watershed and highest in KW-III (0.19) (Fig.4.16) possibly due to high drainage density.

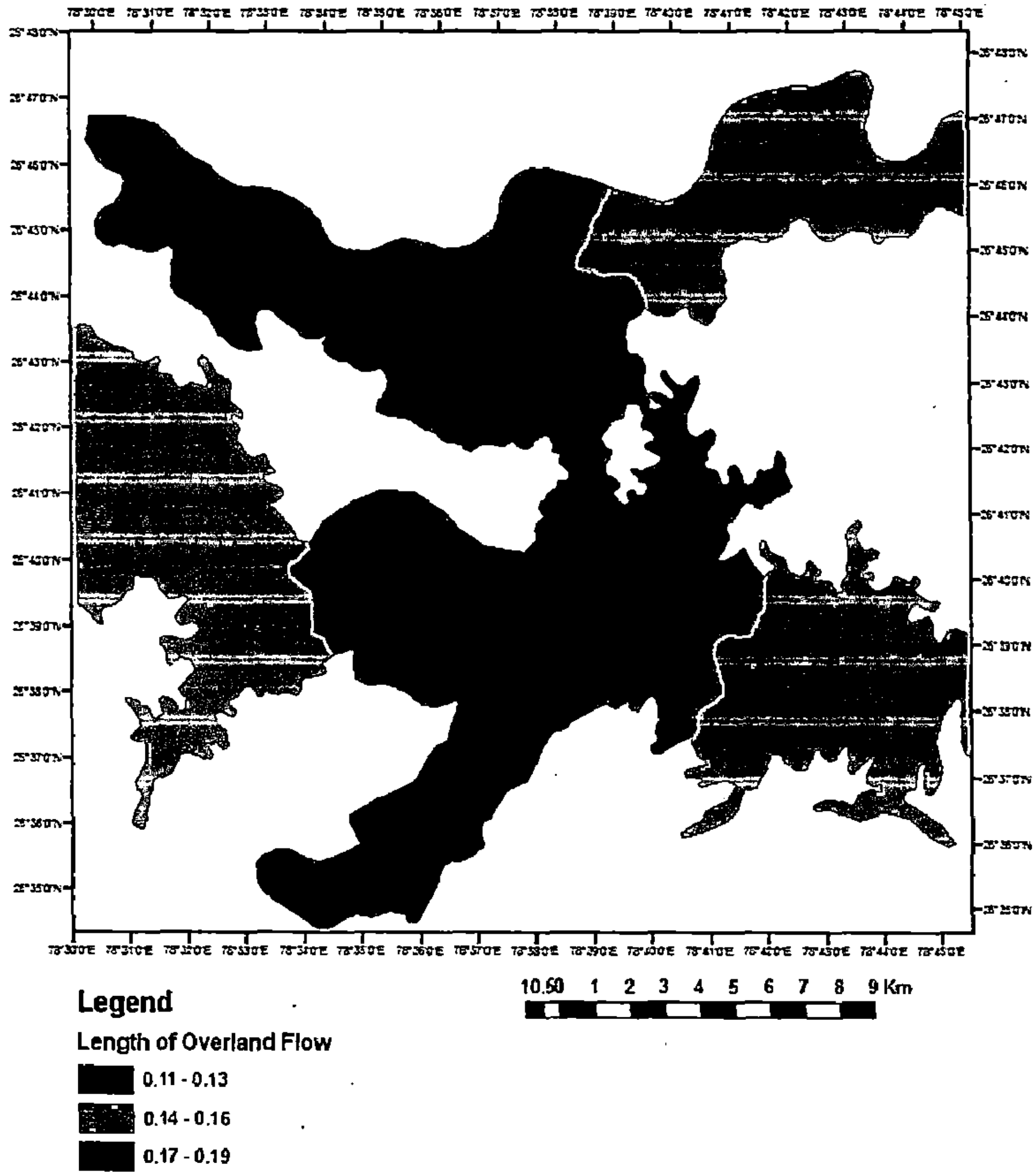


Fig.4.16: Length of Overland Flow Map

4.4. Relief Aspects of Drainage Network

4.4.1. Maximum Basin Relief (H)

Maximum basin relief is the elevation difference between basin mouth and the highest point within the basin perimeter. Maximum basin relief can be determine by the given formulae:

$$H=H_{max} - H_{min}$$

Where,

H_{max}= maximum height in sub-watershed
H_{min}= height at basin mouth

In order to obtain the potential energy of drainage system, the values of maximum basin relief for drainage basins were determined and presented in the Table 4.7. Digital elevation map (Fig.4.17) generated from ASTER DEM gives elevation range of 110-175m in the drainage basin. Higher the value of maximum basin relief, greater the potential energy, results into higher rate of erosion. Sub-watershed CH-III has the highest value indicating maximum runoff potential where sub-watershed KW-I has the least runoff potential.

4.4.2. Relief Ratio (Rh)

When basin relief (H) is divided by the horizontal distance it results in a dimensionless ratio called relief ratio which is equal to the tangent of the angle formed by two plane intersecting at the mouth of the basin. Schumm (1956) measured relief ratio as the ratio of maximum basin parallel to the principal drainage line. Relief ratio measures the overall steepness of a drainage basin as an indicator of the intensity of erosion process operating on slope of the basin (Schumm, 1954). Melton (1957) used relative relief expression in percent. Relief ratio is determined by using the formulae:

$$Rh = \frac{H}{Lbmax}$$

Where,

H = maximum basin relief
Lbmax = maximum basin length

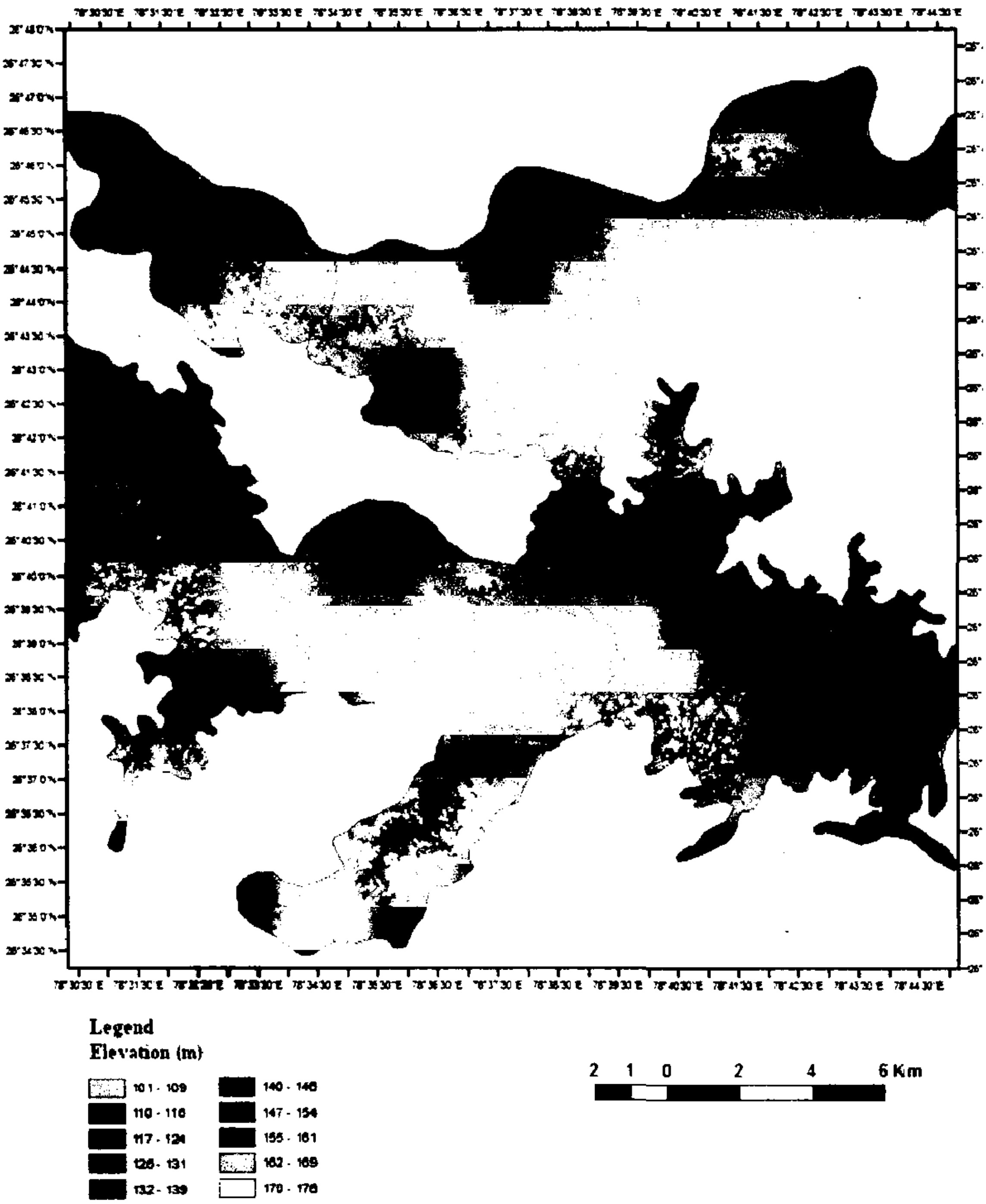


Fig.4.17: Digital Elevation Map of Drainage Basin

High value of relief ratio indicate steep slope and high relief though small value indicate the presence of basement rocks, exposed in the form of small ridge and mount with gentle slope. High values are characteristic of hilly region and low values are characteristic of peniplain and valley. The relief ratio generally increases with decrease of drainage area and size of the given drainage basin (Gottochlk, 1964). The values of Rh are given in Table 4.7 ranges from 0.002 (KW- IV) to 0.006 (CH-I). Relief ratio is higher in Chambal sub-watershed and lower in Kunwari sub-watershed. This can be seen in the slope map (Fig 4.18) also where slope is as high as 16^0, found in all the sub-watershed of Chambal river, clearly indicate high erosion in Chambal basin.

Table-4.7: Gradient Aspect Parameters of Various Sub-watersheds

Name of Sub-watersheds	Elevation		Max. Basin Relief (km)	Relief Ratio (Rh)	Relative Relief (Rhp)	Ruggedness Number (HD)
	Source point (m)	End Point (m)				
CH-I	160	106	0.054	0.006	0.15	0.17118
CH-II	159	120	0.039	0.004	0.12	0.156
CH-III	160	112	0.048	0.005	0.19	0.20928
KW-I	157	125	0.032	0.003	0.05	0.0944
KW-II	158	124	0.034	0.003	0.07	0.12274
KW-III	163	125	0.038	0.003	0.08	0.0988
KW-IV	162	128	0.034	0.002	0.06	0.1156

4.4.3. Relative Relief (Rhp)

Relative relief termed as 'amplitude of available relief' or 'local relief' is defined as the ratio of maximum basin relief and perimeter of basin. This term was used by Melton, (1957) and can be determined by using the formulae:

$$Rhp = \frac{100\,H}{P}$$

Where,

H = Maximum basin relief

P = Perimeter of the basin (km)

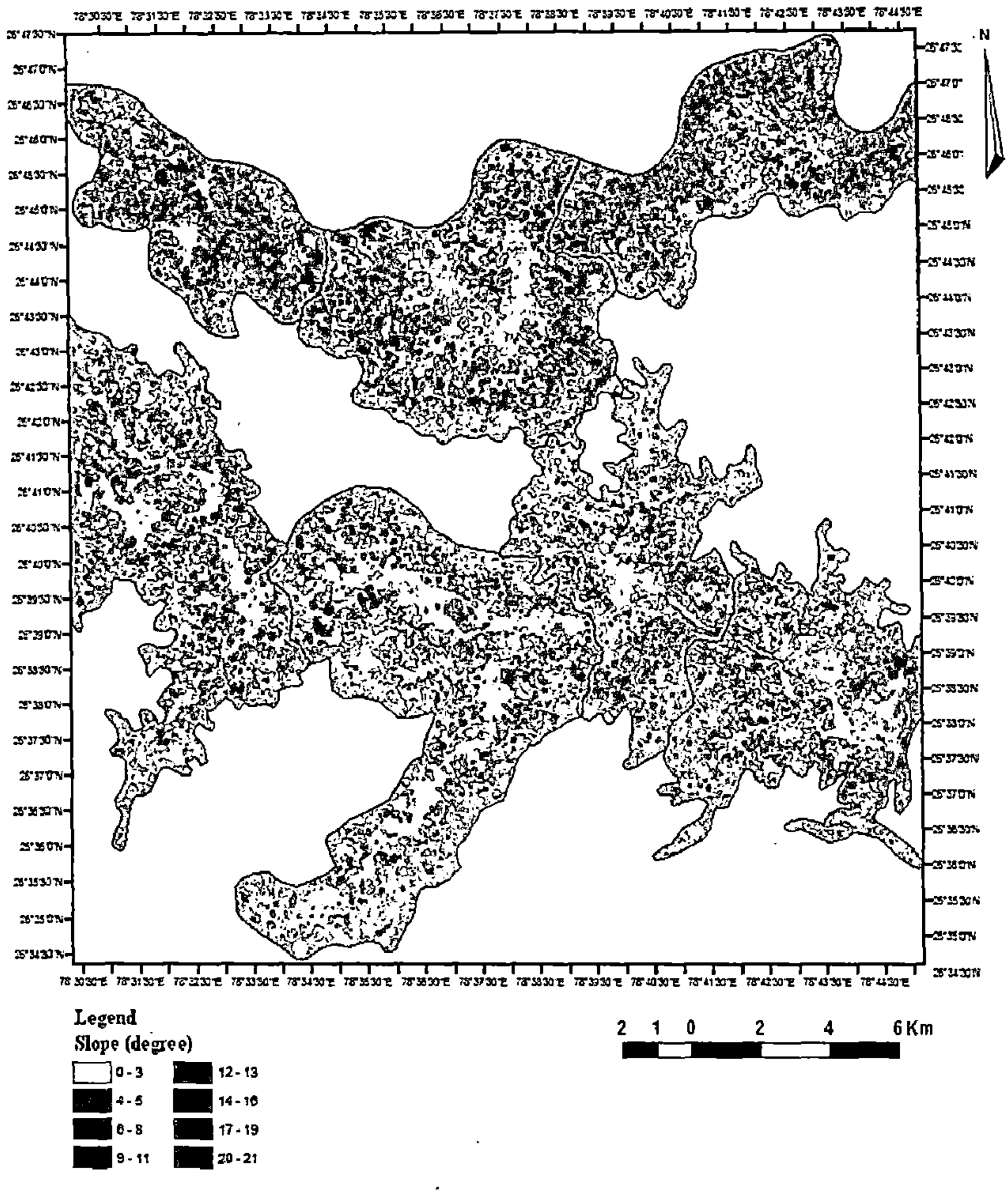


Fig. 4.18: Slope map of Drainage Basin

The relative relief of different drainage sub-watersheds were determined and given in Table 4.7. The maximum value of relative relief is determined in CH-III sub-watershed and the minimum value in KW-I sub-watershed. The relative relief is co-relatable with maximum basin relief.

4.4.4. Ruggedness Number (HD)

It is the product of maximum basin relief (H) and drainage density (Dd), where both the variables are large, generally when slope is not only steep but long as well (Strahler, 1958) and can be determine by using the formulae:

$$HD = H * Dd$$

Where,

H = maximum basin relief

Dd= drainage density

In the present study the value of ruggedness number ranges from 0.09 to 0.20. The higher value of ruggedness number indicates the uneven topography, lithological heterogeneity of terrain and high amount of dissection, moderate values indicate flat topped surfaces or ridges and valley topography and moderately high degree of dissection. However, lower values in the area indicate less dissection and leveled surface (Govind, 2007). High values of ruggedness number are found in all the sub-watersheds of Chambal river where sub-watershed CH-III is having the highest value. Lower values are determine in Kunwari sub-watersheds, suggesting more dissection and ruggedness in Chambal basin than Kumwari, however, both the basin have suffered high dissection which is characteristic of ravines and gullied land.

CHAPTER – V

Geomorphology

Geomorphology

5.1. General Statement

Geomorphology is the study of external landscape of the earth's crust which stands as an evidence not only for the palaeo-morphotectonic and morpho-dynamic activities but also for the present day geological processes. This makes geomorphology substantial in understanding the evolution of the earth and related resources, environment/ecosystems and disaster proneness. Remote sensing from aerial photography to satellite images, constitutes a powerful tool for improving accuracy and precision of extensive large scale geomorphological surveys, makes it possible to investigate previously untestable areas. With the advancement of remote sensing, scope of geomorphology has too phenomenally widened as fabrication and animation of modern geologic/geomorphic processes to be carried out easily. Geographic Information Systems (GIS) and the availability of high resolution elevation data have been used for the classification of landform. Digital elevation models (DEMs) in conjunction with terrain analysis algorithms can be used to extract landform components (Blaszczynski, 1997, Dymond, et. al., 1995).

5.2. Regional Geomorphology

The lower Chambal valley region is characterized by very low geomorphic feature and low geomorphic index. The district of Bhind and Morena, dominated by fluvial geomorphology caused by evolution of Chambal rift valley (Singh, 1969) represents the isostatic readjustment in Chambal basin. The region is drained by Chambal, Son, Narmada rivers and their tributaries which bring sediments from Himalaya and Vindhyan uplands. Geomorphology of Morena district is marked by valley fills, pediplain, pediment and Vindhyan hills. Valley fills and valley flats are the major landform of the district while pediplain is found along the major rivers. Pediment zone is found around the Vindhyan hills having an elevation of about more than 440m (Fig.5.1). Most of the area of Bhind district is occupied by vast older flood plain and the major geomorphic units include older flood plain, flood plain, structural hill and valley, structural plain and denudational slope. Flood plain is found along the major rivers and their tributaries while structural hill and valley, structural plain and

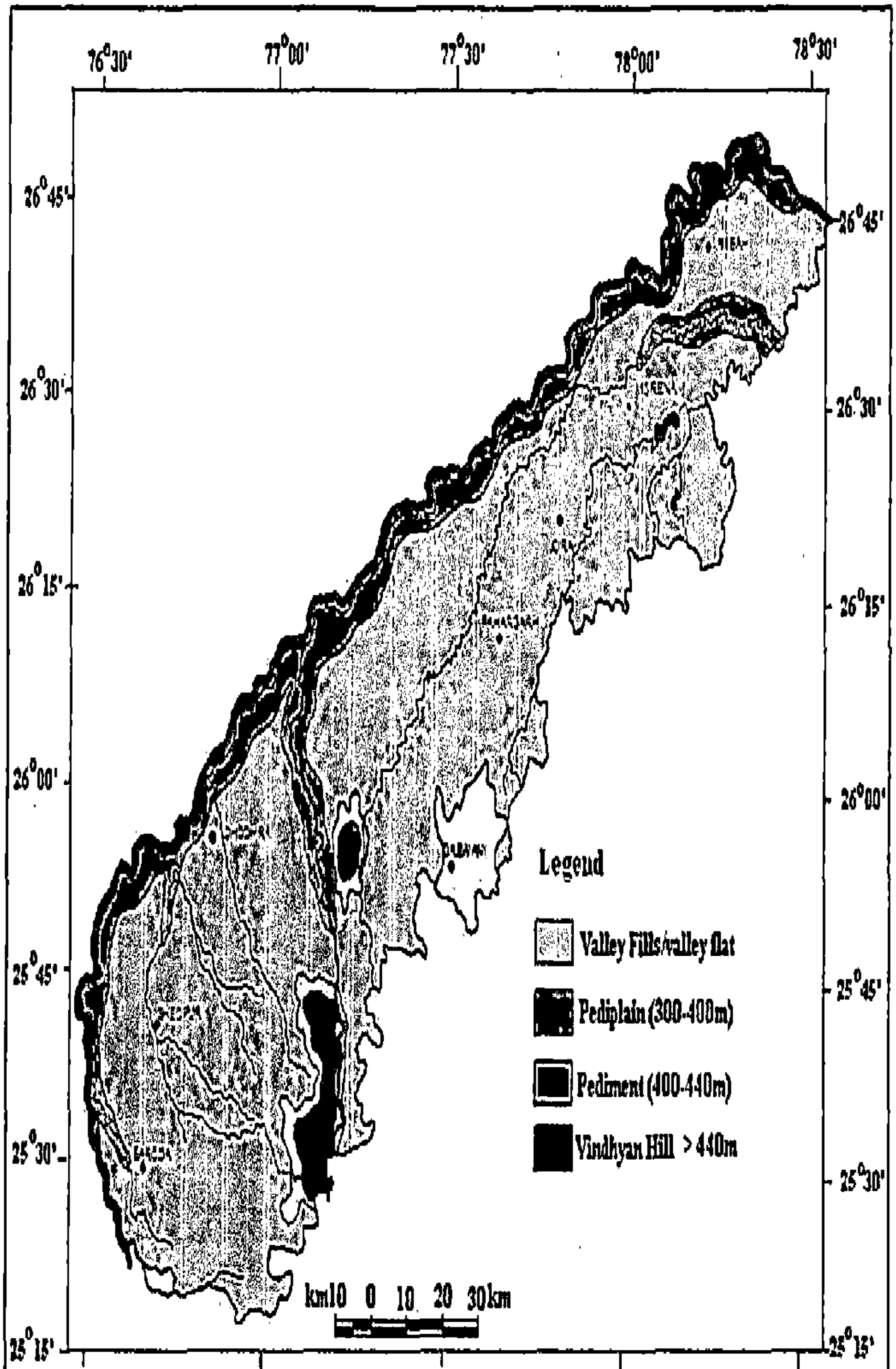


Fig. 5.1: Geomorphological Map of Morena District

denudational slope is restricted in the south-western part of the district. In this area landform is mainly alluvium, followed by structural plains of the Vindhyan Supergroup and Gwalior Group. There is general lack of extensive flood plain in the Chambal valley (Fig.5.2) since aggradations in Chambal Valley has ceased and the rivers are engaged in degrading the older deposits resulting in uneven ravines.

5.3. Geomorphology of Study Area

IRS-P6 LISS-III, 23.5m multispectral data and CARTOSAT-1, 5m PAN data is used to delineate and demarcate various geomorphic units. These geomorphic units are further categorized and the image characters of these identified geomorphic units are given in Table-5.1. The various geomorphic units in the study area are characterized by fluvial geomorphology and are divided into following broad categories:

1. Older Alluvium Zone
2. Badlands Zone
3. Terrace Zone
4. Recent Flood Plain

5.3.1. Older Alluvium Zone

The older alluvium zone, known as Varanasi older alluvium is formed by the flood plain deposit of Chambal river. The alluvium is sandy in nature and occupy higher topographic region, found at a distance from the current river deposit, occupies major part of the study area. The upland area is generally devoid of natural vegetation and being extensively cultivated (Pl. III, Fig.1). The Varanasi older alluvial plain is sandwich between the badland of rivers and show polycyclic sequence of clay and silt with calcareous and ferruginous concretions. Due to its location it is not nourished periodically and is covered with Bhanger soil. This soil is dark in colour and forming hard calcium carbonate nodules, known as kankar. In the study area older alluvium has a sharp and irregular contact with the ravines with uniform topography. Varanasi Older Alluvium on image is identified by its bright red to white tone exhibited by cropland and fallow land respectively, mottled texture, sharp contact with adjacent geomorphic unit, gentle to moderate slope and association with agriculture activity and at places show paleochannels or abandoned channels.

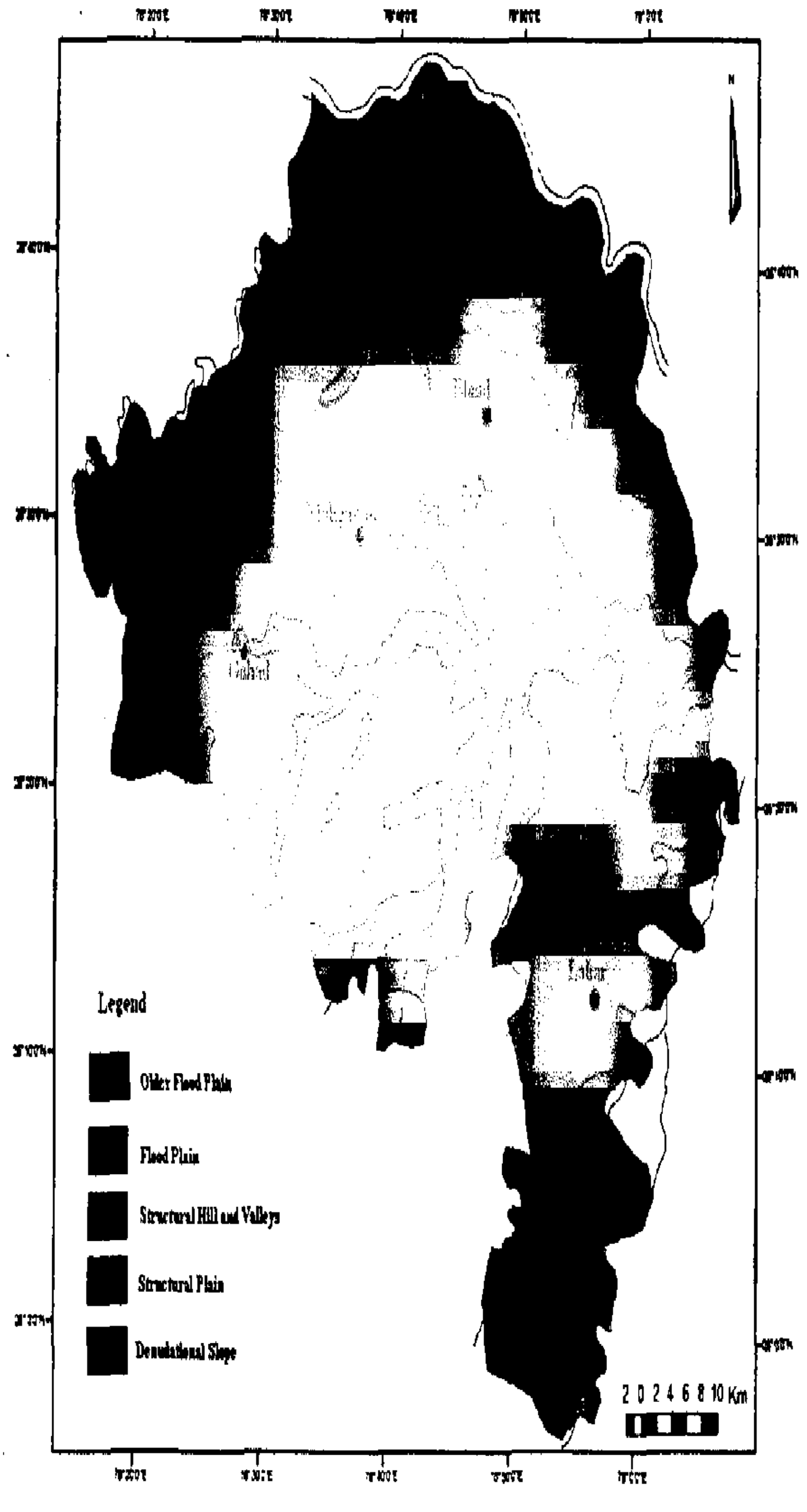


Fig. 5.2: Geomorphological Map of Bhind District

Palaeochannels are the deposits of unconsolidated or semi-consolidated sediments, deposited during ancient time and mainly found in currently inactive river and stream channel systems. The palaeochannels formed by the natural or anthropogenic factors, appear geologic/geomorphologic body of the abandoned channel resulting from changes in hydraulic conditions (Wu, 2008). In the study area, paleochannels on satellite image are identified by their shape and tonal character. The variation in tone is due to divergence in physical properties of soil from its surrounding area. The direction of paleochannels in the study area is NW-SE, linear to curvilinear fashion and joins streams of Kunwari river (Fig.5.3).

5.3.2. Badland Zone

The badland zones are characterized by deep gullies with steep gradient, vegetated and barren ravines. Soil characteristics, geology, neo-tectonism and ecological factors have played an important role in the formation of these ravines. Active gully systems commonly develop in unconsolidated materials due to changing pattern of land use and associated changes in the river basin. The development of ravines in the catchment of the Chambal and Kunwari river is very conspicuous and extensive. Ravines found all along the river channels which encroach upon the catchment area by head ward growth, preserved as rejuvenated morphology, covered by alluvium and shale in the area. The severe gulling is initiated by upliftment of table land and lack of maturity in base level of Chambal and Kunwari river.

Ravines on satellite image are identified by their association with river channel, dark red tone, rough texture and sharp contact with other geomorphic unit's namely older alluvium, younger alluvium and terrace zone. Ravines show contact with older and younger alluvium but at places directly with T_2 terrace. This indicates that at such places younger alluvium has been completely eroded and possibly converted into ravines. Such ravines may be termed as terrace ravines. Ravines of Chambal and Kunwari show different stages of development. Chambal ravines are very deep and vegetated as compare to the Kunwari ravines. Due to vegetation cover Chambal ravines have become dead while Kunwari ravines are still active and expanding with time.

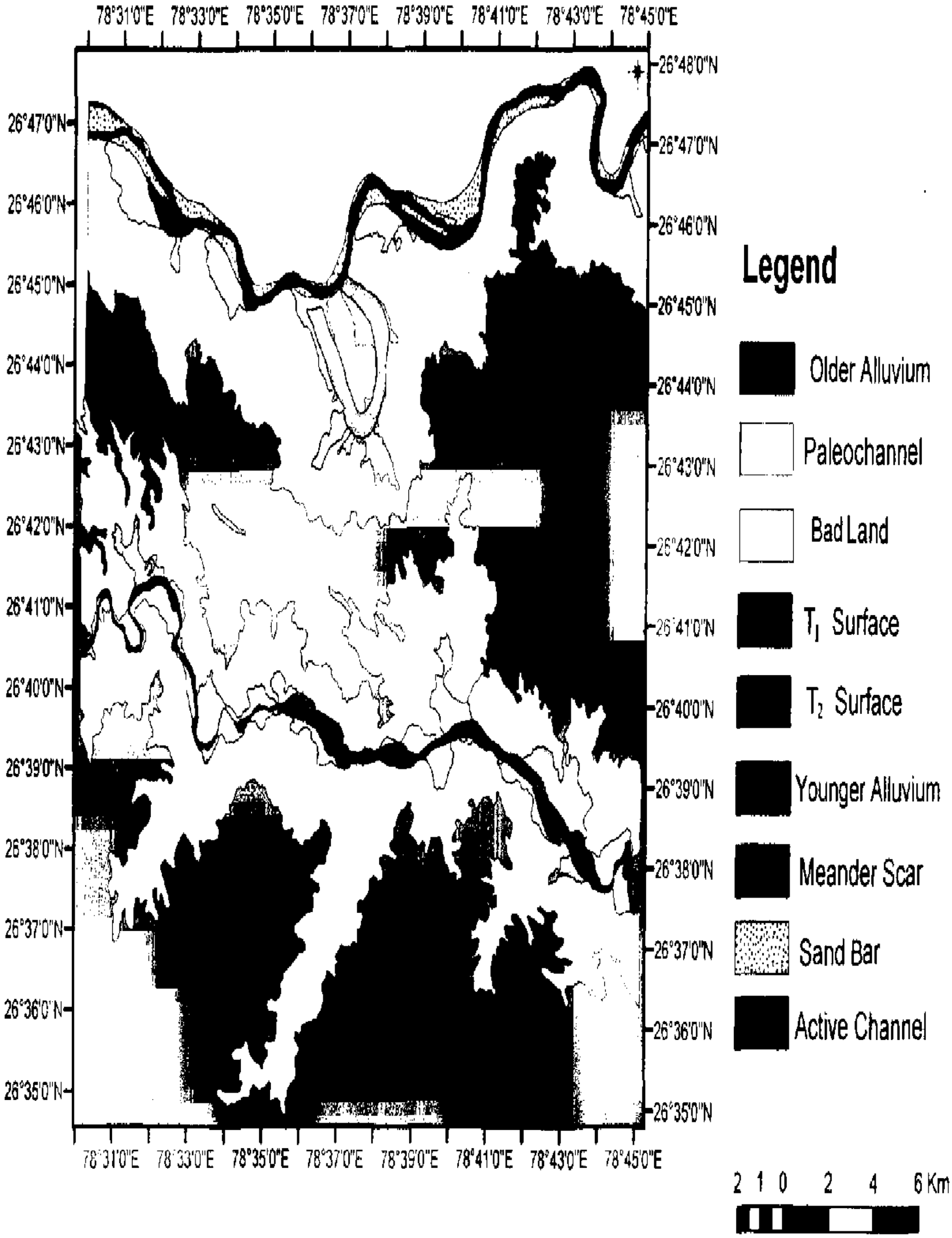


Fig.5.3: Geomorphological Map of the Study Area

5.3.3. Terrace Zone

The alluvial landforms (terrace zone) build up as a result of downward cutting of stream into a previously deposited floodplain. These depositional features found along the narrow zone of the rivers and above the current floodplain level. These features are not affected by recent fluvial processes. The terrace representing composite surface, formed by the coalescence of T_1 and T_2 level terraces (Samdhani, 1990 and Iqbaluddin, 1992) are similar in lithological character and have limited aerial extent. Further, small scale meander scar is also noted in the terrace Zone of Kunwari river which might have resulted from the siltation of the tributary of Kunwari river.

T_1 terrace: T_1 terrace observed in Kunwari river, indicating more active nature of Kunwari river and higher topographic location. This also indicates that aggradations have stopped in Chambal watershed and cutting deeper ravines. Further, T_1 terrace in both the river valley indicates development of broad river valley in the past indicative of humid climatic regime (Ghosh and Singh, 1988). T_1 terrace is squeezed between T_2 terrace and recent flood plain. The contact between T_1 and T_2 surfaces is gradational (Fig.5.3). T_1 terrace, on satellite image is identified by its smooth texture, medium to light tone, absence of vegetation, association with river channel and linear to curvilinear shape. The signature of agriculture activity is observed in high resolution CARTOSAT-1 image but clear demarcation of agricultural fields is not traceable on the image.

T_2 terrace: T_2 terrace represents the paleo-flood plain of Chambal and Kunwari river which occupy higher topographic level from T_1 terrace surface (Pl.III, Fig.2). Kunwari river is more frequent in number but less conspicuous in extend than that of Chambal river (Fig 5.3). T_2 surface of Chambal is wider and indicates broader paleo-flood plain. On CARTOSAT-1 image extensive agriculture activity is observed in T_2 terrace in linear and curvilinear pattern, while IRS-P6 LISS-III image show medium to dark tone and uniform texture.

Meander Scar: Meander scar is produced by a meandering stream and represents the remnants of a meandering water channel, characterized by a crescentic cut in a bluff or valley wall. A small meander scar is found in the terrace zone of Kunwari river which is identified by its characteristic shape. The meander scar

Table-5.1: Geomorphic Units and their Characteristics

Geomorphic Zones	Geomorphic Units	Image Characteristics	Lithology
Recent Flood Plain	Point Bar/Channel Bar and other T_0 Surfaces, Ingrown Meander Scar	Bright tone of bars, characteristic shape and location, shape of meander, dark tone and associated agricultural activity.	River Alluvium: High fraction of silt and clay with admixture of very fine sand.
Terrace Zone	T_1 and T_2 surface, meander scar and younger alluvium	Dark tone, uniform fine to medium texture and smudged pattern of T_1 surface, rectangular grid pattern of T_2 surface, Pattern of agricultural field in a preferred shape in T_1 surface. Younger Alluvium do not have uniform pattern of agriculture.	Younger Alluvium: Fine clay and silt are more comparing to sand. High moisture retaining capacity.
Badland Zone	Gullied/ ravines	Rough texture, very dark to light tone, irregular boundary and sharp contacts. Dark red tone due to poor quality of natural vegetation and light tone is of bare gullied surface.	Alluvium: Both younger and older alluvium is present since the extension of badland is enormous. Brown soil with calcareous nodules
Older Alluvium	Varanasi Older Alluvium and paleo-channel	Medium to dark tone, irregular boundary, bright tone of agriculture field, uniform slope and dominant agriculture activity.	Older Alluvium: Fine to medium sand with intercalation of silt and clay. Yellow and black colour soil.

formed by sediments deposited by the tributaries of Kunwari river, clearly indicates deposition of sediments resulting into shifting of stream course due to change in flow dynamic rather than any geological factor. Meander scar is formed near the meandering loop of Kunwari river (Fig.5.3) and not show any shifting and orientation of scar related to the tributary of Kunwari river as deciphered from the CARTOSAT-1 image. The region around the meander scar is occupied by ravines but due to compact and cohesive nature of channel alluvium and higher elevation this meander scar is used for cultivation.

Younger alluvium: This unit is composed of slightly consolidated to cemented material. The light gray, unconsolidated alluvium consisting of fine-grained sand, laminated clay and silt, easily identified on image by extensive agriculture activity without any particular pattern and dissection by streams. The patches of younger alluvium occur in ravine land and used for cultivation. Formation of rill (Pl.IV, Fig.1) and gullies (Pl.IV, Fig.2) can be seen in cultivated younger alluvium.

5.3.4. Recent Flood Plain

Recent flood plain in the study area include those low lying, gently sloping areas along the river which gets inundated during peak flow under the effect of current river activity. However, in the recent flood plain, a large scale incised meander is found which indicate lowering of the base level due to rejuvenation, Chambal river abandoned the T_1 surface and simultaneously meander is also formed with gradual movement of active meandering river channel.

Sand Bars: Sand bars are long ridges of sand or silt laid down and sediments deposited by the river when the payload capacity of river decreases. Sand bars are found associated with different flow regime depending upon the shape of channel and location of deposition. Various types of sand bars such as point bars, lateral bars and longitudinal bars are identified in the study area on IRS-P6 LISS-III FCC by their bright tone due to presence of fine sediments like sand and silt, smooth texture, characteristic shape and association with river channel. Sand bar is the youngest geomorphic unit and is collectively designated as T_0 surface. Point bars (Pl.V, Fig.1) are dominantly lateral accretion deposits occur inside the meander bends and laterally migrate into the Chambal rivers. Point bars consist of gravel and/or coarse sand on the upstream end and mud drapes or alternating mud/sand layers at the downstream end. In the study area both active and stable point bars are developed on the convex inside banks of meander, generally following the alignment of the meander. The sparse and scanty vegetative cover and isolated beds of sand, superimposed on the bar indicate that sand bar (Pl.V, Fig. 2) is active and exhibits encroachment on downstream banks. Stabilized point bars are characterized by vegetation cover and sometimes by incised gullies across the bar. These bars are identified by presence of vegetation at edges which show red colour on FCC with bright tone, indicate healthy vegetation. Some stable point bars show gullies, which indicates longer period of stability. These bars are more clayey in nature than that of active bars which have more sand content. Active point bars are more common in Kunwari river and they keep on changing more rapidly and hence not traceable. Lateral bars (Pl.VI, Fig.1) occur along the banks of low-sinuosity reaches and are found at the lateral side of the channel between the channel meanders. Classic alternate-side lateral bars are rare in the study area, but lateral bars are found in short relatively straight reaches between meanders. At places longitudinal bars, formed by river deposit sediments within the channel where the transport capacity is exceeded by sediment supply in mid channel, are also found. Longitudinal bars are mid-channel features oriented parallel to flow and more-or-less streamlined, often with a downstream oriented teardrop shape (Pl.VI, Fig.2).

Incised Meander Scar: Long period of upliftment results into the formation of incised meander scar (Pl.VII, Fig.1). Ingrown meander scar, a type of incised meander is identified from the study area and possibly formed due to result of the gradual upliftment. The slow upliftment of flood plain in Chambal watershed causes lateral shifting of river, leaving behind abandoned meander. A very prominent ingrown meander scar is found in the recent flood plain of Chambal river which indicates the shifting of the channel. Cutoff meanders are commonly detached at their narrow necks through normal erosional processes, but in present case the meanders scar is not very tight and the separation between the two arms is about 1 km. Such extensive feature is indicative of neo-tectonic activity rather than normal process of erosion and deposition or change in hydraulic condition. It gives contrasting dark tones in a characteristic winding fashion in association with curvilinear cropping pattern and linearly oriented vegetation. This prominent unit is found between ravines near Ater and is extensively cultivated due to the presence of fertile river alluvium soil and higher topographic position acquired and siltation of dried channel. One limb of the loop boarders point bar whereas other is in contact with river channel. Field investigation showed that dissection of meander plug is due to regression of river water during peak flow period and flooding.

CHAPTER – VI

Morphology and Genesis of Ravines

Morphology and Genesis of Ravines

6.1. General Statement

Millions of hectares of agriculture land in the country degraded by ravines and gully erosion which is extending every year. Soil losses by running water is a serious problem and is a complex phenomena governed by a large number of factors, such as rainfall, soil erodibility, slope and land use etc. Along the rivers ravines are formed because of their flow at lower level from surrounding table land, covered with thick, soft and unconsolidated alluvium. The land degradation from water-induced soil erosion appears to be a serious problem in India and only fragmentary information on the factors affecting soil erosion is available. An attempt is made to prepare a current ravine map of the study area for land use planning. Change detection study has also been carried out in order to analyze the effectiveness of remedial measures for soil conservation and reclamation of affected land for useful purpose. Recently in response to worldwide land degradation problem and sustainability issues, multi disciplinary approach based on geomorphic and terrain criteria have been taken up in conjunction with remote sensing techniques. GIS technique is also used to study the erosion of watershed which has high potential regarding efficiency of analysis and accuracy in the estimation of erosion.

India is having about 3.67 million hectares of ravine land constituting 1.12% of total geographical area (National Commission of Agriculture, 1976). Out of the total ravenous land about 3 million hectare is found along the Chambal river itself. In past ravine erosion, as such, was not recognized as a severe problem outside India, resulting ravine researches confined only to the India (Haigh, 1984). In order to prevent ravines formation and to make proper landuse and irrigation practices it is pertaining to reclaimed the ravine lands.

6.2. Chambal Ravines

Among various ravine zones of India, the ravines of Yamuna and Chambal are of very severe type. The Chambal ravines seems to be originated from tectonic activity as there is no obvious relation has been established with climate till date, but continuous deforestation exposes the nutrient deficient soil, which exacerbates ravines expansion. Further, there is no historic record of initiation of ravine erosion in India is available (National Commission of Agriculture, 1976) but it date back to pre-Mughal (Habib, 1963). The erosion starts with splash of rain drop which digs into unconsolidated soil and gradually erode it. Presence of vegetation cover could prevent the first stage of erosion and also facilitate infiltration which prevents runoff. Even though the study area of Chambal basin have substantial forest cover and characterized by rich biodiversity, undulating topography coupled with loose-sandy to sandy-loam soil, renders the area highly susceptible to land degradation and erosion. The sub-surface geology and neotectonism appear to play an important role in the formation of enormous ravines in the study area.

Ahmad (1973) proposed a peripheral uplift of the peninsular shield, pressed against the Himalayas and suggests that the discontinuous pattern of incision is due to differential rates of disturbances. Sharma (1980) pointed out that there is no simple correlation between intensity of human occupancies or deforestation and intensity of ravine erosion along the margins of the Deccan Trap. Geomorphological studies exemplify the polycyclic character of river valley in peninsular India (Sharma, 1979, 1980). Western theories relating ravine and gully erosion with the climate find little support within the Indian scientific community as major ravine zones are found in the areas of low to moderate rainfall. The enormity of the Chambal ravines, which achieve depths of 60 to 80 m, inclines arguments towards the geological explanation in the formation of these ravines. Neotectonics may have paved the way for ravine erosion by lowering the base level of Chambal river and is aggravated by human activities. Although ephemeral gully erosion is responsible for significant soil losses and little is known about the contributing factors.

6.2.1. Delineation of Ravines

Bhind and Morena district of Madhya Pradesh are worst affected by the ravines, extending over an area of 3.20 lakh hectare (Prasad, 1988). In these districts of Chambal region, the unconsolidated alluvial soil, coupled with deforestation, increasing population pressure, faulty irrigation projects and short-term developmental schemes seems to have increased the formation of ravines, resulting in loss of productive lands. From field survey it appears that ravines of Chambal and

Kunwari river are found at various stages of development. Very deep ravines with dense forest cover to initial swallow hole stage of ravines development have been identified in the study area. On LISS-III image of P6 satellite Chambal ravines show dark tone with red hue whereas Kunwari ravines show lighter tone: The different tonal characters of ravines appear due to presence of dense forest cover in Chambal ravines and absence of vegetation in Kunwari ravines. The periphery of Chambal ravines has a sharp contact with the older alluvium, whereas Kunwari ravines show gradational contact. The gullied land is being used for agriculture purposes. These peripheral gullied lands on satellite image show bright white tone in dry season and rough texture in monsoon season. It is estimated that about 948 villages in Bhind and Morena districts are affected by the ravines. Isolated patches of land in the ravenous area are mainly used for agriculture purposes.

Further, the position of Chambal ravines shows gradual changes in its position from 1975 (Annexure-6.1) to 1990 (Annexure-6.2) due to encroachment towards the river and vegetative cover. Overlay map of Chambal ravines (Fig.6.1, Annexure-6.3) show that the gullied land along the bank of river were reclaimed in the year 1990 and used for agriculture and settlement till 2007. However, in the year of 2007, encroachment of ravines toward river is noted with some marginal increase towards the table land (Annexure-6.4). Ravines around Ater village were also reclaimed for agriculture purpose in 1990 but again converted into gullied land (Annexure-6.5) due to faulty agriculture practices. Overlay map (Annexure 6.6) show minor increase in aerial extend of Chambal ravines from 1975 to 2007, possibly due to stabilized vegetation in the area. In Chambal infested ravines, the presence of dense forest in the eastern part and inaccessibility to the area, reclamation works experiences not to be very effective. The overlay map (Fig.6.2) of Kunwari ravines show small isolated patches in the eastern part during 1975 (Annexure-6.7) which expanded and coalesced in 1990 (Annexure-6.8). The headward extension of Kunwari ravines from 1975 to 1990 (Annexure-6.9) shows that erosional activity increases continuously results in the expansion of ravines. Further, there is expansion of ravines toward table land (Annexure-6.10) in 2007. Overlay map show reclamation of some ravenous area and expansion in other region during the period 1990 to 2007 (Annexure-6.11). There is a tremendous increase of ravine land in Kunwari watershed towards fertile land from 1975 to 2007 (Annexure-6.12) mainly in the eastern part appear possibly due to lack

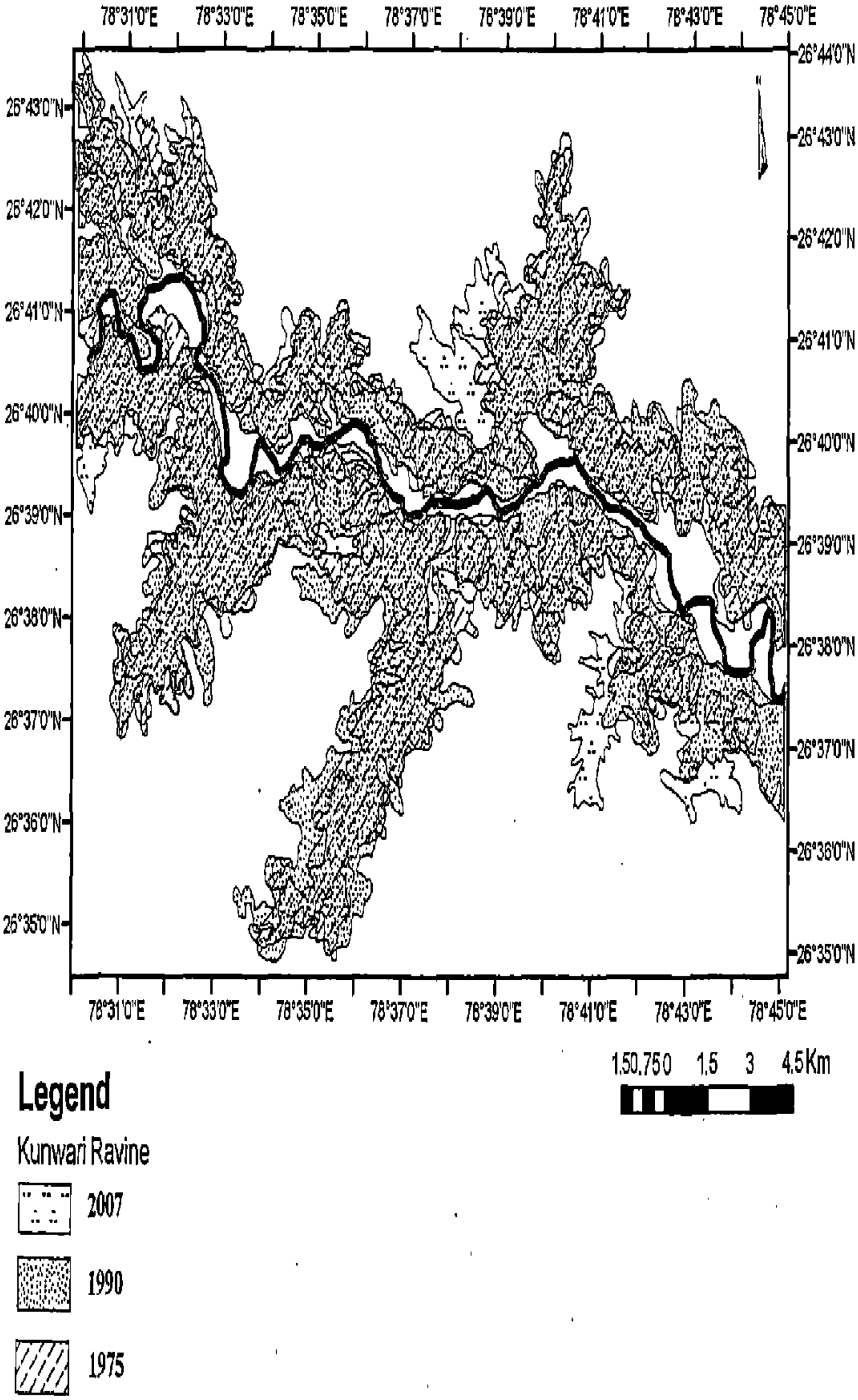


Fig.6.2: Overlay Map of Kunwari Ravines in the Study Area between 1975 and 2007

of vegetation and faulty agriculture practice.

6.2.2. Morphology and Mechanism of Ravines Development

Aerial pattern and size of ravines and gullies are mostly related to the soil and its thickness. In the study area presence of deep gullies and their formation indicate advance stage of ravine development. Ravines follow a pattern of development, marked by vertical head cuts and banks, which give them a typical rectangular cross section. The development of V-shape ravines (Pl. VII, Fig.2) indicate that the soil and sub-soil are mainly friable and easily eroded by flowing water. Linear, long and narrow ravines formed due to down cutting of streams of Kunwari river (Pl.VIII, Fig.I) and Chambal river (Pl.VIII, Fig.2) are formed along drainage line after progressive soil erosion, indicates extension of ravines through active head ward erosion. Kunwari and Chambal ravines, categorized into four stages of development, namely shallow-swallow hole stage, piping stage, collapsing stage and recession stage (Sharma, 1982). In the study area, initial shallow- swallow hole stage (Pl.IX, Fig.1) can be seen in the flat ground of Chambal river by mutual action of rain water and soil containing calcium carbonate nodules. Stage-2 starts when shallow-swallow holes become linked to walls on incising master channel by pipe and steepening of the local hydraulic gradient. The piping stage can be seen near Chambal river (Pl.IX, Fig.2) which indicate sub-surface head ward extension of many vertical cuts. Piping stage is the result of sub-surface removal of soil particle by percolating water, leaving void in the soil profile. These voids allow flow of water which concentrated at sub-surface level tends to remove the soil, leading to formation of tunnel in the study area (Pl.X, Fig.1). Further, collapse of roof of pipes exposes the subterranean pipe system leading to third stage of ravine formation possibly due to continuous soil creep. Slumping of valley wall (Pl.X, Fig.2) increases the width and flow of water from the catchment, helps to develop side channel which eat into the adjoining fertile land. This gives rise to bulbous ravines (Pl.XI, Fig.1) which indicates recession stage of ravine formation. Further, enlargement of bulbous ravines give rise to compound ravines which is quite common in Chambal watershed (Pl.XI, Fig.2). The ravines of Kunwari and Chambal rivers show different stages of development, marked by their structure and morphology. The Kunwari ravines show expanding trend while Chambal ravines are stabilized, probably due to subsequent growth of plants and dense vegetation (Pl.XII,

Fig.1). This indicates final recession stage of ravine development. Though, at some places gullies are found with stabilized ravines of Chambal indicating initiation of new cycle of erosion (Pl.XII, Fig.2).

6.2.3. Change Detection

More than one hundred miles long ravine belt of Kunwari stretches continuously having width of one mile all along the river banks in the eastern part of Morena and Bhind before joining great ravine belt of Chambal. Chambal river has carved out and notorious ravines over 5 miles in width running to the entire length along the bank in Morena and Bhind district, extending further southward from the Yamuna confluence to about 480 km to the town of Kota in Rajasthan. The study carried out by Chambal Command Area Development Authority suggest that the ravines in these two district have increased from 2.28 lakh hectares in 1943-44 to 2.34 lakh hectares in 1950-51 and 3.11 lakh hectares in 1975-76, show an increase of about 36% during last 32 years (Singh, 1997). Tejwani, et. al., 1975, considered that there is an increase of about 810 ha ravine land every year in Morena, Bhind and Gwalior districts. In the present study change in the aerial extend of ravines has been demarcated from year 1975-2007. The study area is occupied by ravines of Chambal river and tributary of Sindh, Kunwari rivers. These rivers have carved and expanded their ravines over a period of hundreds of years. Ravines of Chambal and Kunwari rivers have been demarcated separately to identify the areas that need more attention. It is observed that the badland of these two rivers have different rate of expansion, hence they differ in character. The change in ravine/gullied land is calculated using toposheet of year 1975. About 92.12 km^2 area around Kunwari river and 77.93 km^2 area around Chambal river was found effected by gully erosion in the year 1975 which is 16.05% and 13.58% of the total area under study respectively. In the year 1990, gullied/ravine land around Kunwari river increased to 122 km^2 as compare to77.23 km^2 of Chambal river. Decrease in ravine area of Chambal river may be due to effect of governmental efforts and new scientific approach in ravines prone areas. However, in 1990 total unaffected land decreased from 403.58 km^2 to374.38 km^2 with net increase of 29.19 km^2 ravine/gullied land in15 years. The increase of ravine/gullied land is observed only in Kunwari watershed. It is further noted that in the year 2007, both the Chambal and Kunwari river show increase of ravine area in their catchments. Kunwari ravines show a tremendous increase from 122 km^2 in 1990 to 132.12 km^2 in 2007 which is about 23.03% of total area under study. Chambal show only minor increase of 0.71 km^2 in year 2007 which is about 0.14% of the total area under study. Graphical representation of the land status of Chambal watershed shows almost constant values with time while Kunwari watershed shows constant increase of ravines in the study area (Fig.6.3 a). The aerial extend of Kunwari ravines is also more than that of Chambal in the study area (Fig.6.3 b) which needs immediate attention. Further, the study shows that 6.99% of the land of the area has been converted into ravine badland in a period of 32 years.

The leveled land delineated in the study area reduced to 374.38 km^2 in 1990 from 403.58 km^2 in 1975 which further reduced to 210.06 km^2 in 2007 (Table-6.1) almost half of the unaffected area initially taken up for present study. In current scenario the rate of increase of ravine land in Kunwari watershed is about 1.25 Km^2/ year whereas in Chambal watershed is almost zero, indicates that Chambal ravines has stabilized and Kunwari ravines is aggressively approaching the agriculture lands. The percentage change in the land status of the study area between 1975 and 2007 (Fig 6.4 a, b, and c) show gradual decrease in leveled and fertile land suggest the areas of Kunwari ravines needs proper agriculture practices should be applied while Chambal ravines needs more serious reclamation measures. It appears that the effort for conservation and reclamation of ravine land initiated by national and state government has not been proven to be very effective.

6.2.4. Genesis of Ravines

There are number of explanations given by various geoscientists regarding the origin and development of ravines land in India e.g. peripheral uplifit of the peninsular shield due to Himalayan Orogeny (Ahmad, 1968, 1973), rejuvenation of the northern foreland of Peninsular India and consequent accelerated incision by northward flowing river (Sharma, 1979, 1980), landuse pattern (Gupta, 1973, Gupta and Prajapati, 1983), Surface runoff mismanagement (Prajapati, et. al., 1982), deforestation, overgazing and ill considered tillage (Kaul, 1962), the intensity and concentration of rainfall during monsoon (Singh, et. al., 1976, Babu, et. al., 1978, Raghunath, et. al., 1982) and erodibility of the deep alluvial soils (Mehta, et. al., 1958,

Table-6.1: Change Detection in Ravine Land between 1975 and 2007

	Area affected by gullies/ravines (km^2)			Area affected by gullies/ravines (%)		
	1975	1990	2007	1975	1990	2007
Kunwari Ravines	92.12	122	132.12	16.05	21.26	23.03
Chambal Ravines	77.93	77.23	77.94	13.58	13.46	13.58
Unaffected Land	403.58	374.38	210.06	70.38	65.23	36.61

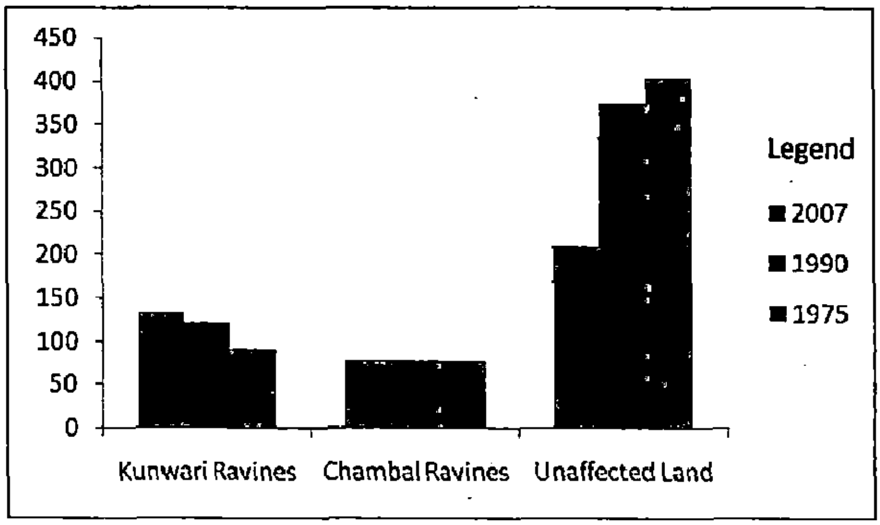


Fig.6.3 (a): Change in Aerial Extent of Ravines (km^2) in the Study Area between 1975 and 2007

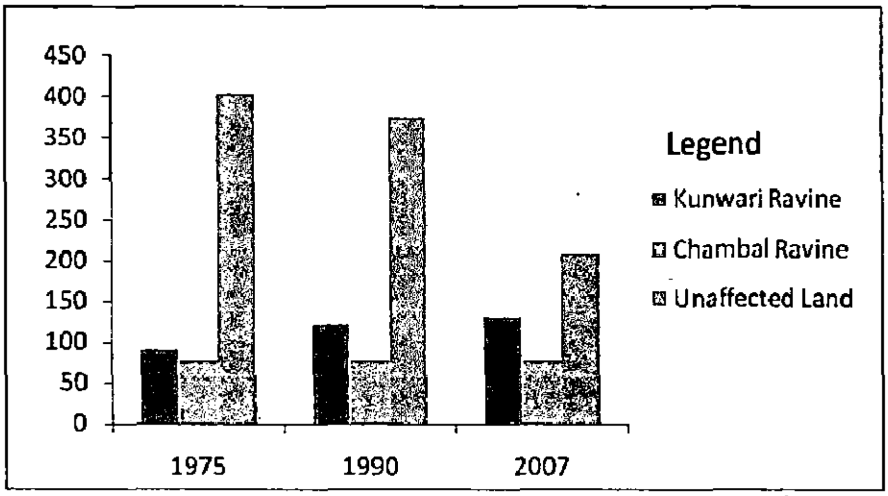


Fig.6.3 (b): Year wise variation in Aerial Extent of Ravines (km^2) in the Study Area between 1975 and 2007

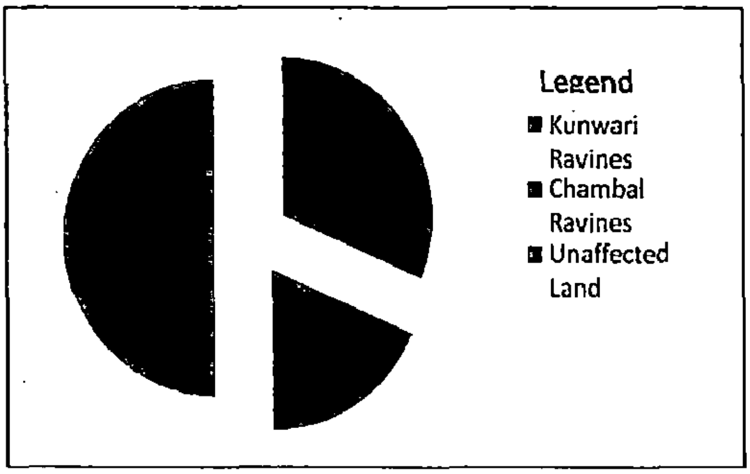


Fig. 6.4 (a): Land status in year 2007

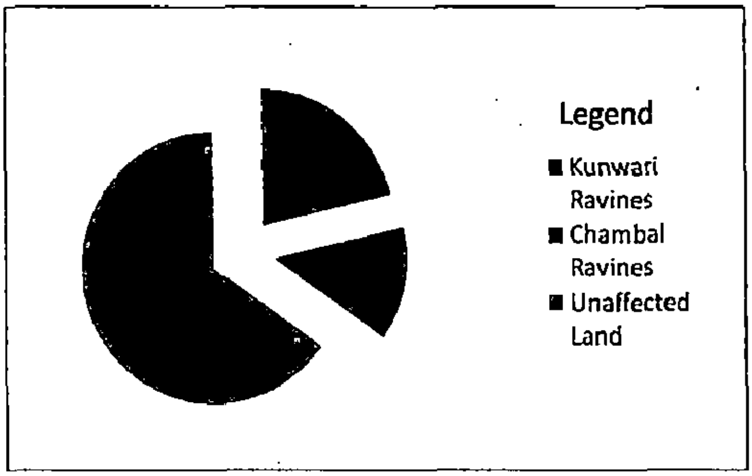


Fig. 6.4 (b): Land status in year1990

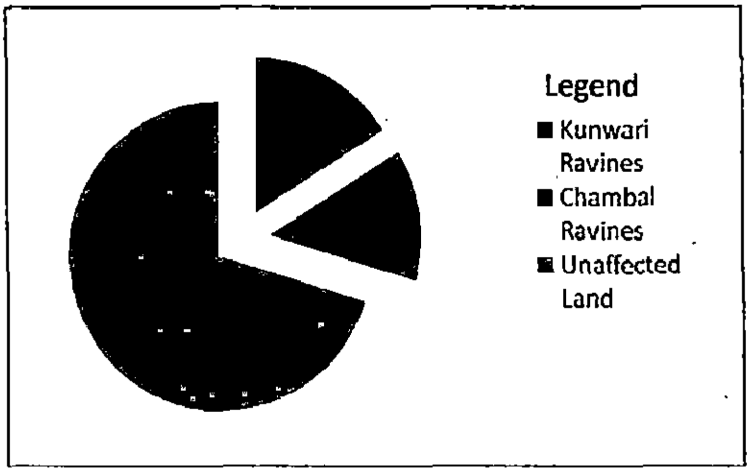


Fig. 6.4 (c): Land status in year 1975

Fig.6.4: Percent change in Land Status of the Study Area between 1975 and 2002

Verma and Patel, 1969, Narain, et. al., 1979). The formation of ravines in tropical and mid latitude countries is forwarded by Bennett (1955) and Brice (1966). Accordingly landuse in which overgrazing and faulty agriculture practices are responsible for gulling. Antevs (1952) and Tuen (1966) proposed climatic change during dry and wet period results the formation of gullies. Schumm (1956) discussed the formation of rills in badland formation as a result of channeling of water on steep slope during rapid runoff. This phenomenon can be seen in the catchments of Chambal and Kunwari river. Though the formation of ravines is initiated by surface process but aggravated by sub-surface processes also. Genesis of Chambal ravines cannot be explained by the above mention theories since the enormous ravines have survived in geological past when anthropogenic factor does not subsisted in the study area. Climatic theory also not explains the formation of ravines as deep as 60-80m. Sharma (1968) and Ahmad (1968) suggested that such extensive zone and gigantic scale of ravines can come into existence by the lowering of local base level of Chambal river due to upliftment of the region. In the study area, geology play a vital role in the formation of such enormous intricate network of ravines and their existence indicates instability of land surface. This instability is also reflected by other geomorphic features such as unpaired terraces, meander scar and limited extent of flood plain of mature Chambal river. This instability may be the result of Himalayan orogeny which is still operative. Continuing northward drift and consequent deformation of the Indian plate has caused accumulation of stresses in the Indian plate and landform which seems to be directly affected by intermittent upliftment of Himalaya. The study area falls in the margin of Peninsular Shield and Indo-Gangetic plain where the bulging would be maximum due to compressing of Indian plate against Eurasian plate. This has caused rejuvenation of Chambal river which acquire a new base level. The rigid shield pressing against the thick pile of Indo-Gangatic alluvium results the down cutting of these sediments. Rejuvenation theory of formation of ravines can also be supported by the fact that Yamuna do not form ravines while flowing through Indo-Gangetic plain but forms ravines at the confluence with Chambal river.

Sub-surface geology also plays a major role in the formation of ravines. Almost entire study area is underlain by Sirbu Shale of the Upper Vindhyan which is generally soft, thinly laminated, splintery and fissile (Pl.XIII, Fig.1). Silty bands observed in valley profile and calcareous shale givie rise the formation of kankar nodules (Pl.XIII, Fig.2 and Pl.XIV, Fig.1), impart the permeability of shale. In semi-arid climate of study area consolidation due to calcareous cementing material causes vertical jointing and block slippage during peak flow of water. During peak flow, water seeps into weathered Sirbu shale and when water recedes, the block of shale collapse within the meandering plug (Pl. XIV, Fig.2). This gives rise to a typical rectangular cross section to the vertical head cut by gulling. At places where shale is covered with thick alluvium cover, receding water removes Sirbu shale therefore formation of ravines start by the tunneling processes. It could be concluded that the formation of ravines in the study area is a result of both plate movement as well as local sub-surface geology.

6.3. Soil Characteristics

Soil character is one of the important variables that affect soil erosion. Physical and chemical characteristic of soil (Table-6.2) suggests that the major portion of the study area is occupied by Typic Ustochrepts subgroup of Ustochrepts Great Group of soil and some area is occupied by the Typic subgroup of Haplusterts. Ustochrepts are classed in the sub-order Ochrepts, in the order Inceptisols. Typic Ustochrepts are the soils of recent alluvium plain and semi recent river terrace characteristic of dry season. These soils are coarse to fine loam in texture, reddish to brown in colour , slightly acidic to alkaline in reaction, low organic carbon and low water transmission characteristic. They are prone to soil erosion by water because of high erosion index. The low moisture retention is possibly due to fine texture, low organic matter content and dominance of illite in clay fraction. These are deep soils of semi-arid region have a shallow horizon in which carbonates are also accumulated.

The other soil type present in the study area include Typic subgroup of Haplusterts, concentrated at depth and do not have significant amounts of salts or sodium. It belongs to Usterts Sub-Order of Order Vertisol. Genetically Typic Haplusterts is black soil and is formed by the weathering of basic rocks in low lying areas of the state. The black colour of soil is due to presence of titaniferous magnetite, humins, bitumins etc (Sehgal, 1996). The soil is neutral to alkaline in reaction having free calcium carbonate nodules at depth. Typic Haplusterts is clayey in texture with tremendous swell-shrink potential and high bulk density. Typic Haplusterts soils are poor in organic matter, calcareous in nature and are of very high cation exchange aracteristic of Soil Samples of the Study Area

SERIES	Depth	Partical Size Analysis			Texture	OC (%)	pH	EC (mmhos/cm)	CEC (me/100g)	Exchangeable Cation (me/100g)				
		Sand	Silt	Clay						Ca	Mg	Na	K	ESP
abhaura	0-11	27	46	27	Clay Loam	0.2	9.5	0.61	15.8	2	4	7.94	0.22	50.2
	11-33	21	44	35	Clay Loam	0.1	9.5	0.79	21.1	3	3	13.0	0.27	61.8
	33-61	23	46	31	Clay Loam	0.1	9.5	0.52	18.3	2	4.25	10.3	0.24	56.4
	61-95	27	44	29	Clay Loam	0.0	9.3	0.33	11.4	2	3.75	4.35	0.21	38.1
	95-120	26	43	31	Clay Loam	0.0	9.4	0.3	9.7	2	3.25	3.22	0.2	33.2
Didee	0-9	31	56	13	Silty Loam	0.4	8.3	0.1	11.3	5.7	1.7	0.16	0.5	5.4
	9-28	21	64	15	Silty Loam	0.1	8.4	0.07	14.9	7.2	4	0.73	0.2	4.9
	28-55	19	63	18	Silty Loam	0.1	8.4	0.07	17.5	8.7	4.5	0.77	0.2	4.4
	55-87	25	59	16	Silty Loam	0.3	8.5	0.07	12.5	7.5	1.7	0.67	0.2	5.36
	87-120	25	59	16	Silty Loam	0.1	8.4	0.07	13.8	8	2	0.68	0.2	4.93
Garoth	0-12	44	24	32	Clay Loam	0.5	8.5	0.07	23.7	1	2	0.8	0.2	3.38
	12-27	44	20	36	Sandy Clay	0.4	8.5	0.07	25.2	2	2.3	0.77	0.2	3.06
	27-66	32	27	41	Clay	0.2	8.5	0.07	30.2	24	4.5	0.82	0.2	2.72
	66-110	28	31	41	Clay	0.1	8.6	0.08	34.3	2	6.5	1.06	0.3	3.09
ssainpura	0-8	25	62	13	Silty Loam	1.1	6.5	0.03	10.1	4	3	0.39	0.2	3.86
	8-29	23	62	15	Silty Loam	0.4	6.7	0.02	9.8	4	3.2	0.38	0.2	3.88
	29-52	17	47	36	Silty Clay Loam	0.3	7.1	0.02	19.9	9	6	0.67	0.3	3.37
	52-85	17	46	37	Silty Clay Loam	0.2	7.1	0.02	20.2	1	5.7	0.74	0.3	3.66
	85-118	17	44	39	Silty Clay Loam	0.2	7.2	0.02	21.4	1	6	0.83	0.3	3.88

Soil Code		Depth	Practical Size Analysis			Texture	OC (%)	pH	EC (mmhos/cm)	CEC (me/100g)	Exchangeable Cation (me/100g)				
			Sand	Silt	Clay						C	Mg	Na	K	ESP
06040518080705010	Lami	0-11	24	40	36	Clay Loam	0.6	8	0.13	26.5	18.2	6	1.06	0.7	4
06040518080705010	Lami	11-35	24	40	36	Clay Loam	0.4	8.3	0.1	24.2	17.5	4.7	1.07	0.4	4.42
06040518080705010	Lami	35-60	24	39	35	Clay Loam	0.2	8.4	0.1	23.5	16.7	4.3	1.07	0.5	4.55
06040518080705010	Lami	60-81	24	47	29	Clay Loam	0.2	8.4	0.1	19	14	2.2	1.3	0.5	6.84
06040518080705010	Lami	81-111	20	39	31	Clay Loam	0.1	8.5	0.1	22	12.2	8	1.19	0.4	5.41
06040518080705010	Lami	111-149	20	47	33	Clay Loam	0.1	8.5	0.11	25.1	10	12.7	1.19	0.5	4.74
06040518080705019	Babai	0-13	57	30	13	Loam	0.1	8.2	0.1	15.9	11.7	2.75	0.67	0.3	3.14
06040518080705019	Babai	13-43	49	30	21	Loam	0.1	8.3	0.1	16.2	12	2.75	0.76	0.3	2.73
06040518080705019	Babai	43-69	45	34	21	Sandy Loam	0.1	8.4	0.1	16	11.5	3.25	0.82	0.3	4.21
06040518080705019	Babai	69-88	39	39	22	Loam	0.1	7.2	0.06	9.7	3.5	2.25	0.21	0.1	4.69
06040518080705019	Babai	88-110	41	34	21	Clay Loam	0.2	7.1	0.06	14.9	8.5	3.75	0.34	0.1	5.12
06040518080705021	Itora	0-16	56	28	16	Loam	0.1	8.4	0.11	17.3	9.5	2.25	0.37	0.1	70.2
06040518080705021	Itora	16-34	44	34	22	Loam	0.08	8.4	0.07	20	8.5	4.75	0.69	0.46	74.3
06040518080705021	Itora	34-57	42	35	23	Clay Loam	0.91	5.9	0.06	14.9	6.5	3.5	0.4	0.36	74.4
06040518080705021	Itora	57-84	42	35	23	Clay Loam	0.46	6.9	0.04	21.2	9.25	5.5	0.46	0.36	70.8
06040518080705021	Itora	84-117	36	39	25	Sandy Clay Loam	0.39	7.2	0.04	20.7	9.25	5	0.46	0.33	70.5
11050513120105004	Mankapur	0-8	14	42	44	Clay	1.9	7.6	0.1	41.3	2	18	0.93	0.7	1.91
11050513120105004	Mankapur	8-32	12	44	44	Clay	1.01	7.7	0.05	43.4	2	18.3	1	0.6	1.86
11050513120105004	Mankapur	32-61	12	42	46	Clay	0.99	7.7	0.05	41.3	1	19.3	1.06	0.6	1.97
11050513120105004	Mankapur	61-106	14	42	44	Clay	0.95	7.9	0.05	32.1	1	10.8	1.3	0.7	2.06

Soil Code	SERIES	Depth	Practical Size Analysis			Texture	OC (%)	pH	EC (mmhos/cm)	CEC (me/100g)	Exchangeable Cation (me/100g)				
			Sand	Silt	Clay						C	Mg	Na	K	ESP
11050513120105O5	Chandsera	0-13	22	37	41	Clay	1.28	6.8	0.04	30.1	1	6	0.76	0.4	3.65
11050513120105O5		13-40	22	37	41	Clay	0.99	6.9	0.02	31.1	1	6.5	0.83	0.3	3.52
11050513120105O5		40-68	20	38	42	Clay	0.79	7.3	0.03	32.4	1	9.5	0.86	0.4	2.05
11050513120105O5		68-94	2	38	42	Clay	0.76	8	0.07	30.5	2	7	1.05	0.4	3.99
11050513120105O5		94-144	14	36	50	Clay	0.45	8.3	0.13	36.9	2	4.8	1.19	0.5	4.03

Table-6.3: Classification of Soil Samples of the Study Area

SOIL-CODE	ASSI-CODE	ORDER	SUB-ORDER	GROUP	SUB-GROUP	FAMILY-TEX FAMILY-MIN FAMILY-TEMP	SERIES	SUB-SERIES
0601030308070502	0601030112010501	Inceptisols	Aquepts	Halaquepts	Aeric Halaquepts	Fine Loamy, Mixed, Hyperthermic	Dabhaura	Daba
0604051812070503	0604051808070510	Inceptisols	Ochrepts	Ustochrepts	Typic Ustochrepts	Fine Loamy, Mixed, Hyperthermic	Garoth	Khwahanjpura
0604051807070503	0604051110070501	Inceptisols	Ochrepts	Ustochrepts	Typic Ustochrepts	Coarse Loamy Mixed Hyperthermic	Didee	Dabhaura
0604051812070507	0604051808070513	Inceptisols	Ochrepts	Ustochrepts	Typic Ustochrepts	Fine Loamy, Mixed, Hyperthermic	Hussainpura	Jatauli
0604051808070510	0604051807070507	Inceptisols	Ochrepts	Ustochrepts	Typic Ustochrepts	Fine Loamy, Mixed, Hyperthermic	Lami	Tawa
0604051808070510	0405051008070501	Inceptisols	Ochrepts	Ustochrepts	Typic Ustochrepts	Fine Loamy, Mixed, Hyperthermic	Lami	Lami
0604051808070510	0604051108070503	Inceptisols	Ochrepts	Ustochrepts	Typic Ustochrepts	Fine Loamy Mixed Hyperthermic	Lami	Jhilmil
0604051808070519	0103081708070506	Inceptisols	Ochrepts	Ustochrepts	Typic Ustochrepts	Fine Loamy, Mixed, Hyperthermic	Babai	Semai
0604051808070521	0604051807070503	Inceptisols	Ochrepts	Ustochrepts	Typic Ustochrepts	Fine Loamy, Mixed, Hyperthermic	Itora	Daba
1105051312010504		Vertisols	Usterts	Haplusterts	Typic Haplusterts	Fine Montmorillonitic Hyperthermic	Mankapur	***
1105051312010505		Vertisols	Usterts	Haplusterts	Typic Haplusterts	Fine Montmorillonitic Hyperthermic	Chandsera	***

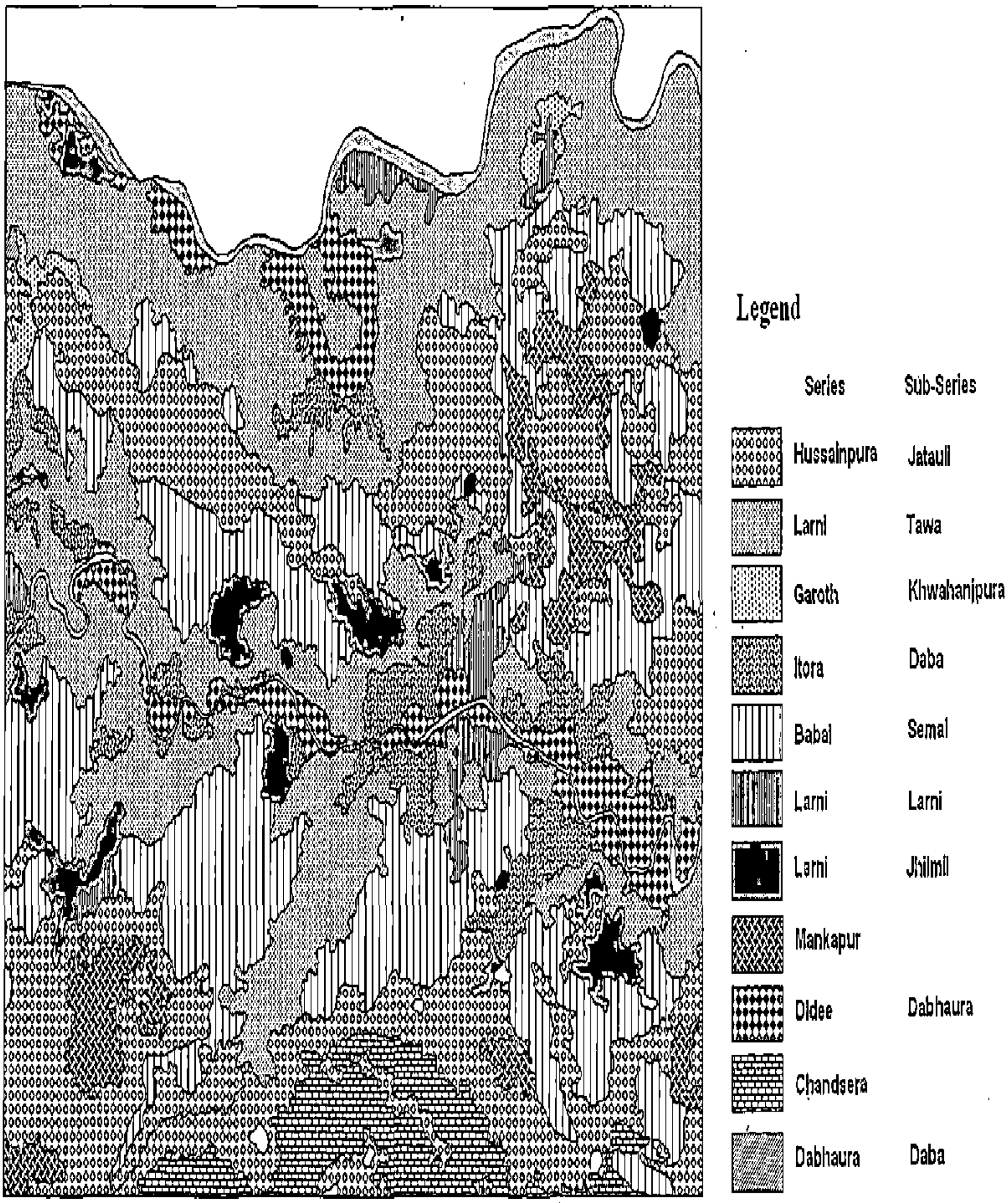


Fig.6.5: Soil Map of Study Area

capacity. These properties make them prone to severe surface erosion with medium to very high erosion index.

Mankapur and Chandsera Series of soil belonging to the Typic Haplusters Subgroup, fine in texture with high clay fraction, silt and sand (Table-6.2). Dominant clay mineral is montmorillonite (Table-6.3). The soil of Mankarpur Series is neutral to slight alkaline whereas Chandsera soil is acidic to alkaline with depth. Exchangeable sodium is very low but CEC is very high (Table-6.2) due to presence of montmorellonite. High CEC indicate that leaching is less and low ESP suggests good soil structure in this series. Itora soil depicts very high ESP values in the order of 74.45 me/100g (Table 6.1) and low Ca and Mg content. Such high value contribute the weakening of soil aggregate and their dispersion under the raindrop effect (Ghadiri, et. al., 2001), raises the surface runoff and contribute the process of soil erosion. Hussainpura soil is characterized by low ESP values which reflect the unity of soil structure. The low CEC at the surface of soil (Table-6.2) indicates loss of fertility due to improper agriculture management. Organic carbon content at the surface of older alluvium plain is favorable and pH changes from slight acidic to slightly alkaline with depth (Fig.6.5). Didee Soil Series is characterized by silty loam with high percentage of silt. The soil is alkaline in reaction and pH varies from 8.3 to 8.5 at depth on low ESP values, suggests erosional process is not active in this soil type. This soil is found as younger alluvium near river channel (Fig.6.5) where sediments were deposited by river and used for cultivation. The agriculture practices near the surface tend to lower the values of CEC which increases with depth with increasing clay percentage.

Soil of Larni Series is alkaline in reaction and has low ESP value but contain high exchangeable calcium, which is indicative of leaching of soil. CEC is also high in this soil series with value of 26.5 me/100g, indicates disintegration and decomposition of soil by water. Babai series of soil is alkaline which decreases with depth. Soil texture is sandy to clayey loam giving high water holding capacity. The high calcium content and more than 7.2 pH results the formation of kankars. CEC suggests moderate leaching whereas ESP value suggests good soil structure of the area. Soil of Garoth series is sandy- clayey loam to clay in texture showing moderate CEC and high pH together with exchangeable calcium, suggest that the soil is prone to precipitation of calcium and formation of kankar. Dabhaura soil series is characterized by clay loam, alkaline in reaction with high silt percentage. The low CEC in Dabhaura soil series show the possibility of leaching and high ESP value suggest poor soil structure, extends in west and confined to a very small part of the study area. Further, inspite of good soil structure but the leaching of nutrient in the older alluvial plain, these soils do not support the growth of vegetation. Within the older alluvium, free calcium is also found in the soil which results in the formation of calcareous nodules that imparts permeability the soil and promotes horizontal movement of percolating water. Soil of younger alluvium and terraces are integrated and not found eroded. These soils are found near the river channel in the ravenous land where agriculture is actively exercised. Soil that covers ravenous land has poor soil structure and could be easily eroded by the surface processes. The variable properties of soil results the different landuse in the study area.

6.4. Reclamation of Ravines

Based on depth and width, the ravines of Chambal are classified as D_0, D_1, D_2 and D_3 (Seth et. al. 1969). Accordingly, very shallow gullies are 1.5m deep and 3m wide are classified as D_0 whereas, shallow gullies having same depth and more than 3m width are classified as D_1. D_2 are moderate gullies with 1.5-5m depth and more than 3m wide, while D_3 types are trenches with 5-10 m depth. Most of the Kunwari ravines fall in D_0, D_1 and D_2 category. These ravines in the study area have formed due to erosion along the natural drainage lines and slumping of valley walls. These ravines have steep walls and uniform slope but at places show irregular slope. Chambal ravines mostly D_2 and D_3 type, characterized by dense vegetation. Secondary ravines within Chambal are shallow in depth, 3m wide exposed in the Chambal valley, classified as D_0 type. According to the classification given by Bali and Karale (1977) to reclaim the ravines for better usage, the Kunwari ravines are mostly Class-III and Class-IV type while the Chambal ravines are Class-IV and V type (Table-6.4). Class-III ravines are found at the periphery of ravine zone and older alluvial plain. This class of ravines can be reclaimed by proper reclamation measures since these are moderate to deep ravines with moderate width and experiencing compound bed slope of 10-15%. It is hinted that construction of terraces can help to prevent the runoff on the blockage of grazing in Class-III ravines. Terraces convey excess water from field at non-erosive flow rate which probably reduce the sediment transport tends to slows down soil

Table-6.4: Ravine Reclamability Groups and their Characteristics (Bali and Karale, 1977)

Group	Reclamibility	Characteristics
Class-I	Very Good	Ravenous lands that can be reclaimed readily with minor reclamation operations of leveling and scraping. These lands include shallow ravines with widths up to 30m or more, simple and compound bed-slope of up to 5%, lack extremes of texture and do not have within a depth of 1.5m a calcareous layer, hard pan, bed rock, salinity or alkalinity. Ground water level is below 2.5m
Class-II	Good	Lands that can be reclaimed readily with minor reclamation operations but require more dozing work than Class-I. The depth and width specification for this group are the same as class-I, but bed-slope range between 5-10%. They have a low frequency of gullies. They also lack extremes of texture, hard pan, caliches, salinity or alkalinity within the depth 1-1.5m
Class-III	Moderate	Lands that can be reclaimed with medium intensity reclamation measures. These lands have moderately deep ravines with narrow-to- moderate width, medium frequency with compound bed slope of 10-15%. Soil texture is moderately fine and fine, often demanding heavy draft. Soils have slight to moderate salinity and/or alkalinity and posses calcium carbonate, hard pan or bed rock within 0.5-1m from the surface.
Class-IV	Poor	Includes medium to deep gullies of narrow width. There are sever limitation due to complex and strong bed slopes, a high frequency of gullies, extremes of textures, salinity and alkalinity, occurrence of hard layers, bed rock or pan within 0.5m from the surface. These lands are very costly to reclaim or may not be suitable for agriculture after reclamation. Reclamation of such lands for horticulture uses is recommended
Class-V	Unsuitable	There are sever limitation for reclamation of these lands for agriculture or horticulture, and area very high cost means reclamation is not desirable. Such lands would be best developed for forestery and grassland.

erosion by surface runoff. Gully plugging and construction of small earthen check dams are also suggested for reclamation of Class-III ravines. Class-IV ravines can be traceable near the periphery of Chambal ravines. At places Class-IV ravines can by mechanically leveled and could be brought under rehabilitation of local villagers who have lost their land due to ravine erosion. These reclaimed land are not correspond well for agriculture but can be used for horticulture. However, reclamation of Class-IV ravines is very costly affair and need continuous attention of the occupant of the reclaimed land. Proper plantation techniques can also help in better germination of seed for strengthening of soil. Class-V ravines occupy most of the ravenous area of Chambal watershed which is severely affected by erosion and cannot be reclaimed. Further, Class-V ravines are not suitable for reclamation due to great depth, inaccessibility and highly complex bed slope. These ravines can be used for agro-forestry where multipurpose trees can be sapled. Acacia a plant of arid region require little use of water is already tried in Class-V ravines to stabilize through aerial seeding. However, the project failed adding more hardship to the villagers since these were thorny bushes. Indigenous variety of plant should be sown in these ravines with a view to develop this region for forestry and grassland. The seedling should be properly treated before the land is seeded.

Reclamation alone is not sufficient to avoid further expansion of ravines in the study area but proper care needs to be taken to sustain the reclaimed land. Sheet erosion and small rills are not considered to be a problem by the farmers in ravine affected area. However, they can be corrected easily through careful agriculture practice such as furrowing, contour binding and other water harvesting practices to prevent runoff. But due to lack of awareness erosion gets attention only when it reaches alarming condition. Soil conservation measures also not get proper attention and fail due to ignorance, illiteracy, poverty, lack of credit facility, and small scattered land holding. In such situation government should take initiative for social reform in the area to reclaim the land under cultivation as well as providing financial support to the farmers in the area.

Summary and Conclusion

Summary and Conclusion

The study area is a part of Bhind and Morena district of Madhya Pradesh included in the Survey of India toposheet number 54 J/9 and 54 J/10. Present study is carried out in Lower Chambal valley between the parallel of 26^0 15' and 26^0 50' north latitude and 78^0 30' and 78^0 45' occupying an area of 574 km^2. The study area lies in the northern region of the lower Chambal basin, characterized by undulating topography formed by the alluvium and deep ravines. Physiographically, large part of Bhind district occupies vast older alluvial plain including infilled river beds, structural plains, structural hills and valleys with denudation slope, restricted to southwestern part. In the south-eastern part the elevation is as high as 190 m above the msl while in the north-western part as low as 149 m above the msl. Physiography of Morena district is represented by NE-SW trending Vindhyan hills having elevation more than 440m above the msl and valleys. The general slope of the area is north and north east. The climate is tropical with average summer temperature of 29^0 C reaches up to 48^0 C and in winter temperature ranges from 10^0 to 27^0 C. The region receives an average rainfall of 700mm of which 90% falls during monsoon season.

Geologically Chambal basin is a junction between north-western lobe of the Vindhyans and south eastern fringe of the Aravalli range. The study area is characterized by the rock formation belonging to the Gwalior Group, Vindhyan Supergroup and Recent Alluvium. The oldest rock units exposed in Bhind district belongs to the Gwalior Group and classified into Singpur, Sitla, Sithauli and Braoli Formations. The Gwalior Group includes sandstone, shale, silt and limestone, exposed at places in the district of Bhind. The rock units belonging to the Vindhyan Supergroup are exposed in the western part of Gohad tehsil of Bhind district forming basement of the alluvium. The Vindhyan Supergroup comprising shale and sandstone, laterite of Cenozoic age and Quaternary alluvium are well exposed in Morena district. Light colour shale is highly weathered and exposed at walls of the river valley, overlain by alluvium. The alluvium is in sequel to Indo-Gangetic alluvium; accumulated in the drainage basin of Chambal and Sindh river. Alluvium varies in colour from brown, yellowish brown to dark grey brown and texture varies from sandy loam, loam, clay loam and clay. Banda Alluvium consists of sand and silt of badland surface represents the lower litho unit of Older Alluvium. The upper litho unit of Older Alluvium is medium to coarse grained having quartzo-feldspathic sand with calcareous nodules at places and referred as Varanasi Alluvium. Clay loam horizon intermixes with calcareous and siliceous concretion locally known as kankar, found within the alluvium layers. Terrace alluvium is restricted along the Kunwari river and conspicuously found absent along Chambal river. Channel alluvium of Sindh Surface comprises quartzo-feldspathic and micaceous sand and silt, occur to the west of Ater town and along Chambal river. Presence of lower litho unit of Older Alluvium (Banda Alluvium) adjacent to upper litho unit of Younger Alluvium (Channel Alluvium) indicates denudational lithology of the area. Further, the study area is characterized by deep ravines presenting varying extent and thickness of alluvium and appears to be affected by uplift of the peripheral bulging of the northern parts of the Peninsula in response to the Himalayan Orogeny.

Various image processing techniques have been used for the identification and delineation of different geomorphological units, ravines and gullies land. Raw Pan images of CARTOSAT-1 of 5 meter resolution was digitally rectified and geo-referenced by taking LISS-III multi-spectral image as a reference image in Erdas Imagine 2011 through an image to image tie down by identifying ground control points (GCPs). Subsequently, a subset of study area was extracted from the entire scene of IRS-P6 LISS-III image corresponding to path-row 98-53 and Landsat ETM+ satellite data corresponding to path-row number 145-42 in Erdas Imagine 9.1 data preparation workstation. The clipped image was then exported as .img file for processing and classification purpose. A mosaic of CARTOSAT-1 images is prepared by matching and splicing together individual images after geo-registering them. The mosaic image was then clipped in Data Preparation Work Station of Erdas Imagine 9.1Software in .img format. In order to enhance different geomorphic features and landforms different band combination of False Colour Composite (FCC), contrast enhancement, pan sharpening, anomaly detection and mathematical edge enhancement filters were applied. Soil samples were analyze to determine pH, Electronic Conductivity (EC), Organic Matter and quantitative determination of K, Ca, Mg and Na. Particle size analysis was carried out to determine the nutrient content of soil. Cation Exchange Capacity (CEC) and Exchangeable sodium percentage (ESP) were also calculated.

Morphometric analysis is carried out using SOI toposheet and updated with CARTOSAT-1 image of Chambal basin. The drainage basin is divided into 7 sub-watersheds to calculate various morphometric parameters which indicate the amount of dissection and surface runoff in the area. Linear aspects of morphometric analysis suggest soft, unconsolidated and less permeable lithology. Elongation ratio and infiltration ratio suggest higher runoff in sub-watersheds. Shape and relief parameters suggest the time taken by water to drain the region. High drainage density and moderate to very fine drainage texture, indicates the impermeable sub-surface litho unit. Stream frequency reflects the erodible nature of soil. These parameters together give clear idea about the erosion activity. The interpretation of ASTER 30m data show that the elevation ranges from 110-170m and slope ranges from 0^0- 3^0 in the watershed. The slope reaches up to 14^0 near the bank of Chambal river where the ravines are very deep.

The dendritic drainage pattern of the area indicates uniform resistance offered by the rocks in horizontal direction. The sub-watersheds CH-II, KW-III and KW- IV have 250 or more first order streams which indicate the soft lithology of high dissection. Out of all sub-watersheds, the CH-II sub-watershed show V^{th} order stream whereas other sub-watersheds characterized by two fourth order stream and no fifth order stream, suggests unconsolidated nature of alluvium cover in CH-II sub-watershed. The higher value of bifurcation ratio in sub-watershed KW-III and KW-IV indicates that the structure have little control over drainage development in these sub-watershed. The other sub-watersheds having bifurcation ratio in the range of 3-5 indicate the presence of very thick alluvium cover over the rocks belonging to the Vindhyan Supergroup. The mean Rb values range between 3.97 and 4.99, appear slightly higher than the range expected for dendritic drainage pattern (3.5-4) indicates that the drainage basin has dendritic to sub-dendritic drainage pattern. Except sub-watershed CH-III all sub-watersheds show that total length of stream segment is maximum in first order and decreases with the increase of stream order, possibly due to flow of stream from high altitude, change in rock type, moderately steep slope and probable uplift across the watershed. In the study area the value of mean stream length varies from 0.44 to 4.43 km, suggest gentle relief and gentle topography of the area. Sub-watershed CH-I, CH-III and KW-IV show increasing trend in stream length ratio from lower to higher order indicating mature geomorphic stage of development whereas the variable stream length ratio in other sub-watersheds suggest late youth stage of geomorphic development. The late youth stage of geomorphic development in the mature stage of river is possibly due to rejuvenation.

Out of total 183 km^2 area of Chambal and Kunwari watershed, the sub-watershed CH–I have maximum drainage area and sub-watershed KW-IV has minimum drainage area. The low elongation ratio values in sub-watershed KW-III indicate low infiltration and high runoff. Such basins are susceptible to high erosion and sedimentation load. Further, this may be attributed the presence of gullied and ravine erosion. Based on the values of elongation ratio the sub-watershed KW-III appears to be highly affected by headward erosion, steep slope, high relief and elongated shape of the basin. All sub-watersheds are elongated in shape as indicated by circularity ratio which ranges from 0.14 to 0.50. The sub-watershed KW-I is being most elongated while CH-II is less circular having circularity value 0.50. Lengthening of the basin indicate the head ward extension of streams through gullies. Low form factor value ranging from 0.31 to 0.50 in sub-watersheds from KW-II to KW-I suggest that these sub-watersheds falls in elongated basin category. These sub-watersheds tends to be elongated having low form factor, indicates that the basin have a flatter peak of flow for longer duration and such basins flood flow is easily manage. The drainage density varies between 2.60 and 4.36 km/km^2 suggest that the area is semi-arid plain with high alluvium loaded stream due to impermeability of sub-surface lithology. High values of drainage density are found in sub-watershed CH-II and CH-III whereas low drainage density obtained in sub-watershed KW-III which clearly indicates the presence of permeable strata in this sub-watershed. Lowest value of channel of constant maintenance found in sub-watershed CH-III and highest in sub-watershed KW-III, indicate undulating terrain and low resistant soil. This also signify high sediment yield in sub-watershed CH-III associated with weak or low-resistance soils, sparse vegetation and mountainous terrain. The high drainage density and low stream frequency in sub-watershed CH-III are corelatable with high drainage density and high stream frequency of sub watersheds CH-II. Both measures reflect the degree of dissection of the landscape. High values of these parameters are possibly due to erodible soil and rock and high rainfall intensity. Further, variable drainage density and stream frequency is possibly due to disproportionate streams length in relation to stream number, where stream segment decreases greatly and no longer proportionate with river length. Stream length also increases due to higher sinuosity of streams results in higher drainage density. These sub-watersheds are texturally categorized as moderate, fine and very fine textured. The sub-watersheds KW-I, KW-II and CH-I have moderate, KW-III, KW-IV and CH-III have fine and CH-II have very fine texture, indicates impermeable sub-surface, soft and weak surficial lithology. Further, thick unconsolidated alluvial cover in the study area produces moderate to very fine texture of drainage. Very high values of infiltration number in all sub-watersheds indicate low infiltration and high runoff and suggest that the condition of gully erosion would be further aggravated due to high runoff potential of the area. Out of all, sub-watershed CH-II show high values of drainage density, drainage texture and infiltration number which makes together this sub-watershed prone to sever soil erosion by water. The length of overland flow in all the sub-watersheds is on higher side and highest in sub-watershed CH-II, possibly due to high drainage density and semi-arid climate. High value of length of overflow attests to the less permeability and high runoff in CH-II resulting in more soil erosion. Highest value of maximum basin relief and relative relief in sub-watershed CH-III indicates maximum runoff potential, whereas low values of these parameters in sub-watershed KW-I indicate least runoff potential. Further, steep slope in all sub-watersheds of Chambal river clearly indicates high erosion in Chambal basin. Highest value of ruggedness number in CH-III and lowest in Kunwari sub-watersheds indicates decreasing amount of dissection and ruggedness from Chambal basin to Kunwari, however both the basins suffered high dissection which is characteristic of ravine and gullied land.

The study area being a part of Indo-Gangetic Plain is characterized by fluvial geomorphology. Geomorphologically the area is divided as (a) Varanasi Older Alluvial Plain, (b) Ravines, (c) Terrace Zone and (d) Recent Flood Plain. The Varanasi Older Alluvial Plain is sandwich between the badland of rivers, showing polycyclic sequence of clay and silt with concrete and ferruginous material. Paleochannel or abandoned channels are picked up within the Older Alluvium and identified by their shape and tonal character on LISS-III image. These paleochannels appear in linear to curvilinear fashion and show high moisture content, trending NW-SE and join streams of Kunwari river. Ravines found all along the Chambal and Kunwari river, have sharp contact with adjacent geomorphic units like Older alluvium, Younger alluvium and at places they are in direct contact with T_2 terrace, clearly indicates younger alluvium has been completely eroded and converted into ravines. Ravines around Kunwari river show gradational contact with the older alluvium plain. The contact zone is used for agriculture purposes where sever gulling has also been observed. Terrace Zones, found along the Chambal and Kunwari rivers and above the level of the recent floodplain, represent the remnant of older flood plain which ceased as base level increase the depth of Chambal river after rejuvenation. T_1 terrace observed along the Kunwari river indicates more active nature of Kunwari river: T_2 terrace represents paleo-flood plain of Chambal and Kunwari river which occupy higher topographic level than T_1 terrace. T_2 terrace in the Kunwari area is more frequent but less conspicuous in extend than that of Chambal river. Wider T_2 terraces of Chambal river clearly indicates broader paleo-flood plain of Chambal river. Meander scar formed by the deposition of Kunwari river sediments is found near the meandering loop of Kunwari river and no major shifting is observed. Orientation of meander scar in not related to the course of Kunwari river but to its tributary and the area around the meandering scar is occupied by the ravines. The compact and cohesive nature of channel alluvium and higher elevation of meander scar is used for cultivation. Younger alluvium is composed of slightly consolidated to cemented and slightly to moderately dissected. The light gray, unconsolidated alluvium consists of fine-grained sand, laminated clay and silt, mainly used for agriculture purposes without any particular pattern and dissection. Isolated patches of Younger alluvium within the ravenous areas are also used for cultivation purpose.

Recent Flood Plain includes the flood plain deposit of Chambal and Kunwari rivers and admits various types of bars namely lateral bar, point bar and longitudinal bars which identified and recognized from the recent flood plain of Chambal river. These bars represent the youngest geomorphic unit of the river and collectively designated as T_0 surface. In the present case active and stable point bars are found along the rivers. Stable point bar is identified by the presence of vegetation at their edge and show healthy vegetation. At places gullies are found immediate to the stable point bar, indicates longer period of stability. These bars are more clayey in nature than that of active bars which contains greater extent of sand. Active point bars are more common in Kunwari river and rapidly change their position. Lateral bars found at the lateral side of the channel between the channel meanders. Classic alternate-side lateral bars are rare in the study area, however lateral bars do occur in short relatively straight reaches between meanders. Longitudinal bars are mid-channel features oriented parallel to flow and more-or-less streamlined, often in a downstream-oriented teardrop shape. A very prominent ingrown incised meander found in the recent flood plain of Chambal river, indicates shifting of the channel. It gives contrasting dark tones in a characteristic winding fashion in association with curvilinear cropping pattern and linearly oriented vegetation. Such extensive feature clearly indicates the possible neo-tectonic activity and straightening of meandering Chambal river. Ingrown incised meander is found between ravines near Ater village which is extensively cultivated, possibly due to its higher topographic position, siltation of dried channel and fertile alluvium soil of the river.

Geology and soil characteristic are the important factors which aid the erosional activity of water and have been taken into consideration in the present study. The different character of ravines in Chambal and Kunwari is the presence of dense forest cover in Chambal ravines and absence of vegetation in Kunwari ravines which makes it more active toward ravine erosion. The periphery of Chambal ravines has a sharp contact with the Older Alluvium while Kunwari has a gradational contact. Change detection through toposheet, Landsat-7 imagery and Resourcesat-1 images of 1975, 1990 and 2007 respectively yield important information for planning socio-economic condition in the region. The ravine/gullied area is demarcated using image processing technique. The result of image analysis indicate that the isolated patches of ravines exposed in the eastern part of Kunwari river in year 1975 expanded further and coalesce together. The ravines show encroachment toward the Chambal river in year 1990 as compare to 1975. Overlay analysis show that along the bank of river gullied land and small ravines appear up to 1975 were reclaimed in 1990. This reclaimed region is used for agriculture and settlement up to 2007. However, in the year of 2007 encroachment of ravines toward river is seen again and some marginal increase toward the table land is also marked. In the Chambal infested ravines due to dense forest and inaccessibility to the area reclamation work has not found very effective. As a result a considerable part of the area is again transformed into ravines.

Thick pile of soft unconsolidated soil of Chambal valley has given V-shape valley which further expands giving rise to a typical rectangular cross profile. Long, linear and narrow ravines with steep wall in Kunwari watershed has resulted from progressive erosion along natural drainage line. Four stages of ravine development in the study area have been identified and recognized include initial swallow hole stage, piping stage, tunneling stage and recession stage. Initial swallow hole stage appear to be formed from mutual action of rainwater and sub-surface geology, found in the flat ground near Chambal river. Piping stage results from sub-surface removal of soil around swallow holes, indicates sub-surface headward extension of many vertical headcuts. These pipes like holes join together and forms underground tunnels. Such tunnels can be seen along the Kunwari river. Slumping and caving of valley walls results into expansion of ravines giving rise to bulbous ravine in the Kunwari river catchments. These bulbous ravines coalesce together and give rise to compound ravines which is the characteristic of Chambal valley. Compound ravines represent advance stage of ravine development. Bulbous ravines of Kunwari are characterised by lack vegetation cover and their lateral expansion, whereas compound ravines of Chambal are vegetated and ceased lateral expansion and at places showing functional downward cutting.

Furthermore, the ravine in the district of Bhind and Morena show an increase of about 36% in ravine area during last 32 years (1975-2007). Ravines of Chambal and Kunwari rivers have been demarcated separately to identify areas that need more attention. It is observed that the badland of two rivers has different rate of expansion as well as different character. The change in ravine/gullied land in the year 1975 were about 92.12 km^2 around Kunwari river and 77.93 km^2 around Chambal river appears to be effected by gully erosion whereas gullied/ravine land around Kunwari river further increased to about 122 km^2 in 1990. The Chambal river shows a reduction in ravine land with 77.23 km^2 in 1990. However, in 1990 total effected land increased from 403.58km^2 to 374.38km^2 in the year 1975 with a net increase of about 29.19 km^2 land. Further, during 2007, both the Chambal and Kunwari river show increase in the ravine area in their catchment where Kunwari again show a tremendous increased of 122 km^2 in 1990 to 132.12 km^2 in 2007. Chambal show a minor increase of 0.71km^2 in the year of 2007 which is about 0.14% of the total area under study. Further the study shows that 6.99% of the land has been converted into ravine badland in a period of 32 years. In the year of 1975 about 403.58 km^2 lands was not found affected by soil erosion which reduced to 374.38km^2 in 1990 and again to 210.06 km^2 in 2007 which is almost half of the unaffected area.

The western theories of landuse, climate and geological phenomenon aggravate the ravines, formed by the upliftment of Himalaya causing rejuvenation of Chambal river. The northward drift of Indian plate has caused instability in the foreland basin and has maximum effect at the peripheral bulging at the junction of Indian plate and rigid peninsular shield. The new base level acquired by the Chambal river, results in incision of deep alluvium soil in Bhind and Morena area suggest that neotectonism and rejuvination results the formation of ravines. Moreover, geology appears to be responsible for the formation of deep ravines in the study area. Almost entire Chambal valley is underlain by soft, thinly laminated and fissile Sirbu shale of the Vindhyan Supergroup. The calcareous shale, promotes the formation of kankar in the soil and consolidation of calcareous cementing material causes vertical joint formation and block slippage during peak flow of rain and flood results into head ward extension of ravine in the study area.

The analysis of Mankapur and Chandsera soil series show high CEC values, suggest the absence of leaching of the soil whereas low values in Itora, Hossainpira and Didee indicate leeching of soil nutrient. Larni, Babai and Garoth have moderate values of CEC indicate the presence of leaching of soil probably due to agriculture activity. High ESP value in Itora soil series, indicate poor soil structure which is affected by raindrop effect, whereas Mankapur, Chandsera, Hossainpira, Didee, Larni, Babai and Garoth have low ESP values show good soil structure that could not be broken by raindrop effect. Larni, Babai and Garoth are alkaline in reaction with high exchangeable Ca ion which promotes formation of calcareous nodules. Although Hussainpurs soil has high exchangeable Ca ion and neutral to acidic in reaction where in no free Ca is found available for the formation of calcareous nodules. Further, inspite of good soil structure and leaching of nutrient, these soils does not support the growth of vegetation. The absence of vegetation and development of calcareous nodules, promote sub-surface extension of ravines by imparting permeability of the soft underlying shale.

Based on the depth and width, the ravines of Chambal are classified as D_0, D_1, D_2 and D_3, where very shallow gullies designated as D_0 are 1.5m deep and about 3m wide. D_1 ravines having same depth but more than 3m width are shallow gullies. Gullies with 1.5-5m depth and more than 3m width are moderate and designated as

D_2. These gullies are found in Kunwari as well as Chambal ravines. Trenches having 5-10 m depth are classified as D_3 and traceable in Chambal ravine zone of the study area. However, secondary ravines of Chambal may be designated as D_0 type. Further, on the basis of reclaimability, the ravines are classified in various categories. Kunwari ravines are mostly Class-III and Class-IV type while Chambal ravines are Class-IV and Class-V type. Class-III ravines can be reclaimed by proper reclamation measures such as construction of terraces, gully plugging and construction of small earthen check dams. Reclaimed land can be used for agriculture but grazing should be prohibited. The reclamation of Class-IV ravines appears to have serious limitation because of moderate- high frequency of gullies with complex and strong bed slope. At places Class-IV ravines can by mechanically leveled and can be brought under rehabilitation of local villagers. These reclaimed land are not fit for agriculture but can be used for horticulture. Class-V ravines are not suitable for reclamation but can be used for agro-forestery where indigenous variety of plant should be sown to develop the region for forestry and grassland. Proper care needs to be taken to sustain the reclaimed land. Sheet erosion and small rills should be corrected through careful agriculture practice such as furrowing, contour bunding and other water harvesting practices to avoid further erosion. However, soil conservation measures do not get proper attention due to ignorance, illiteracy, poverty, lack of credit facility, and small scattered land holding.

The present study provides a complete database and possible utilization of remote sensing and GIS techniques in the study of inaccessible area. The study evaluate the impact of technical contribution made by various government agencies and views of different geoscientists which does not seems to help the socio-economic condition of the study area. Geology, geomorphology, morphometric and soil analysis shows that the study area has been severely affected by soil erosion. Further, the study suggests that neotectonic activity and isostatic rejuvenation of Chambal river appears to be responsible for the formation of such enormous ravines. However, faulty agriculture practice and deforestation is contributing towards the erosional process initiated 400 years ago with Himalayan orogeny. Different classes of ravines require different reclamation measure that needs to be sustained since soil erosion is a continuous process that needs continuously attention. Fresh scientific approach, government intervention and public effort are the need of hour to curb the menace of ravines.

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Web Pages

WebPages

http://cgwb.gov.in

http://www.gdem.aster.ersdac.or.jp/search.jsp

http://glcf.umiacs.umd.edu/index.shtml

http://www.saga-gis.uni-goettingen.de/html.index.hph

http://www.visualizationsoftware.com/3dem.html

http://earth-info.nga.mil/gandg/geotrans

Field Photographs

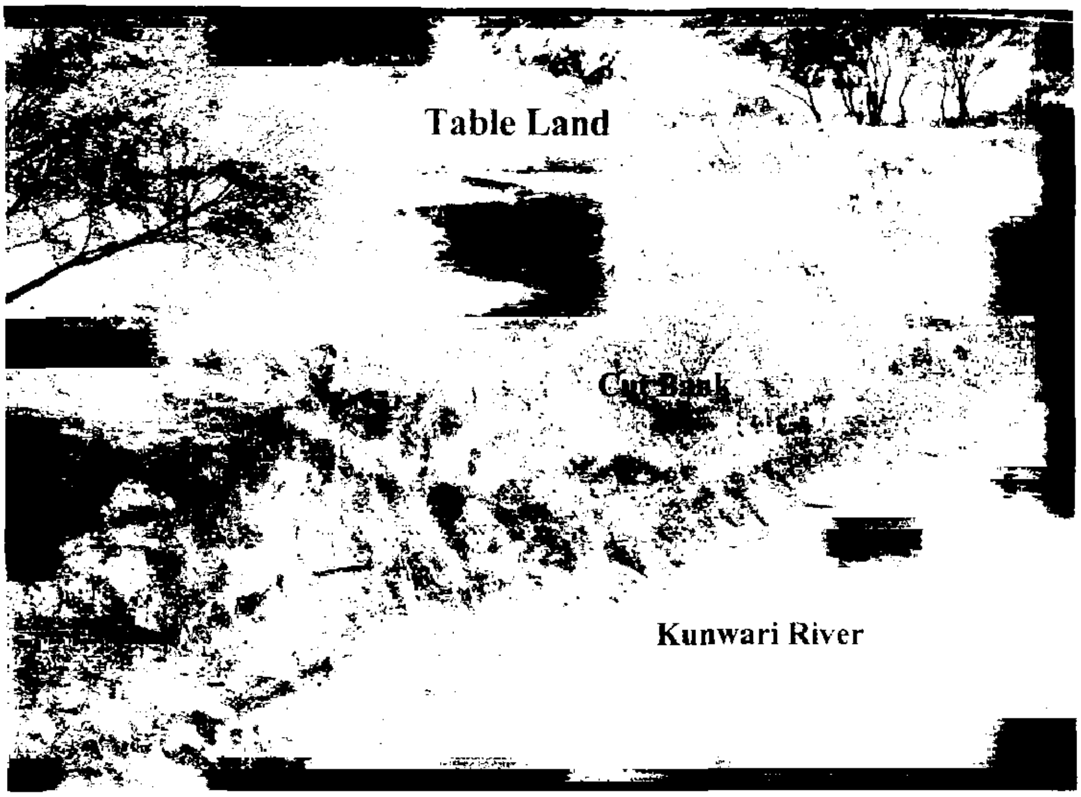


Fig. 1: Upliftment of table land around Kunwari River

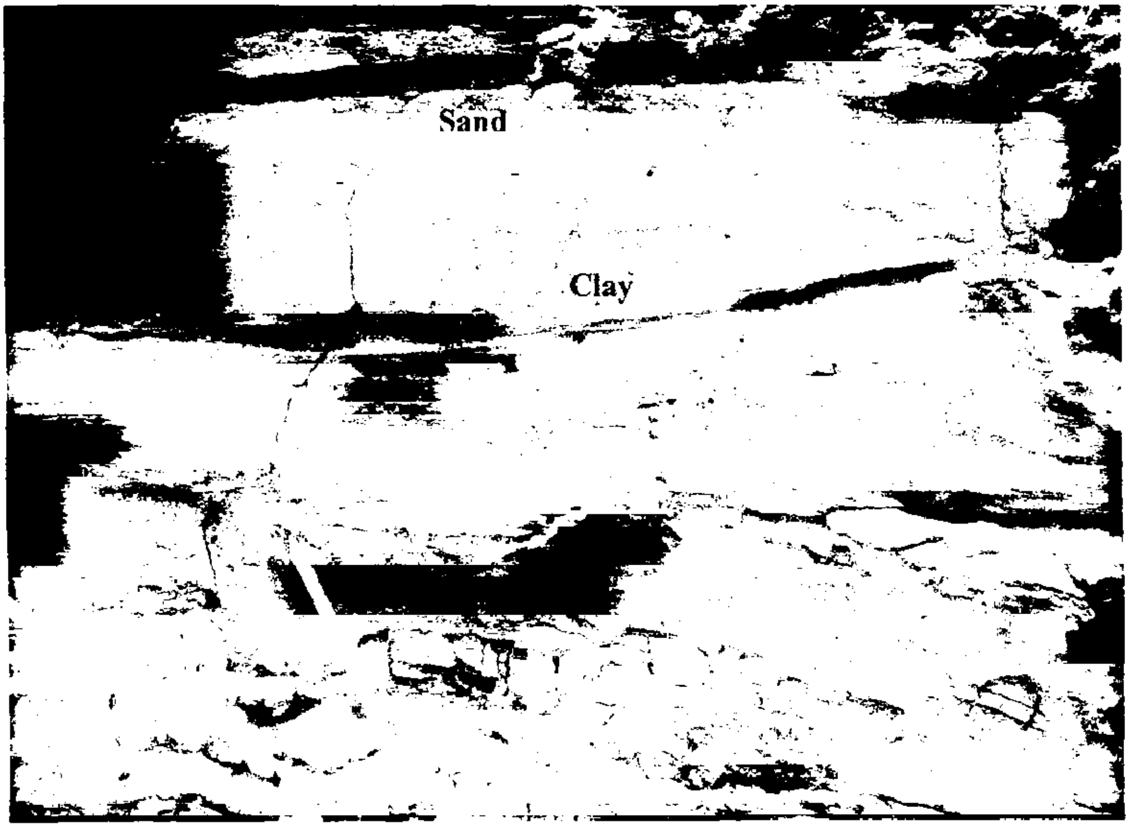


Fig. 2: Polycyclic sequence of Sand and Clay

Plate-II

Fig. 1: Lithology of Chambal Ravine

Plate-III

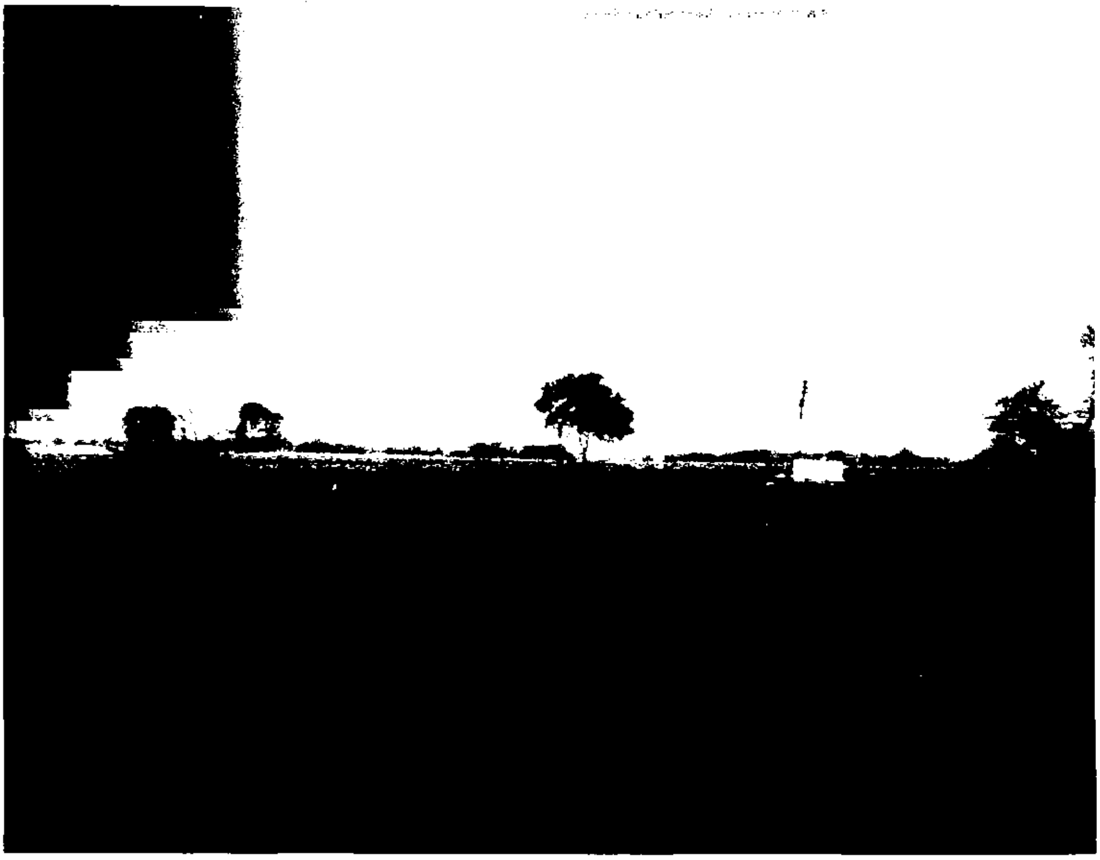


Fig. 1: Older Alluvium used for agriculture, Para, Bhind

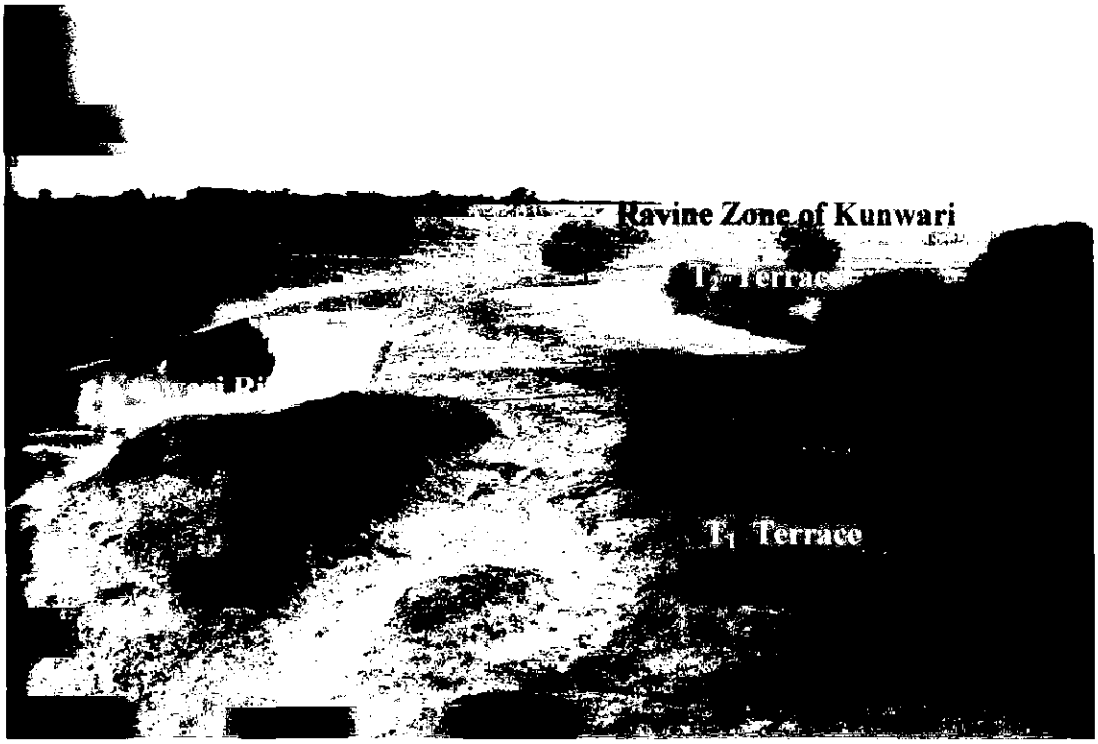


Fig. 2: Terraces (T_1, T_2) and ravine zone around Kunwari River

Fig.1: Highland showing rills around Younger Alluvium near Chambal River

Fig.2: Gullies in Younger Alluvium near Chambal River

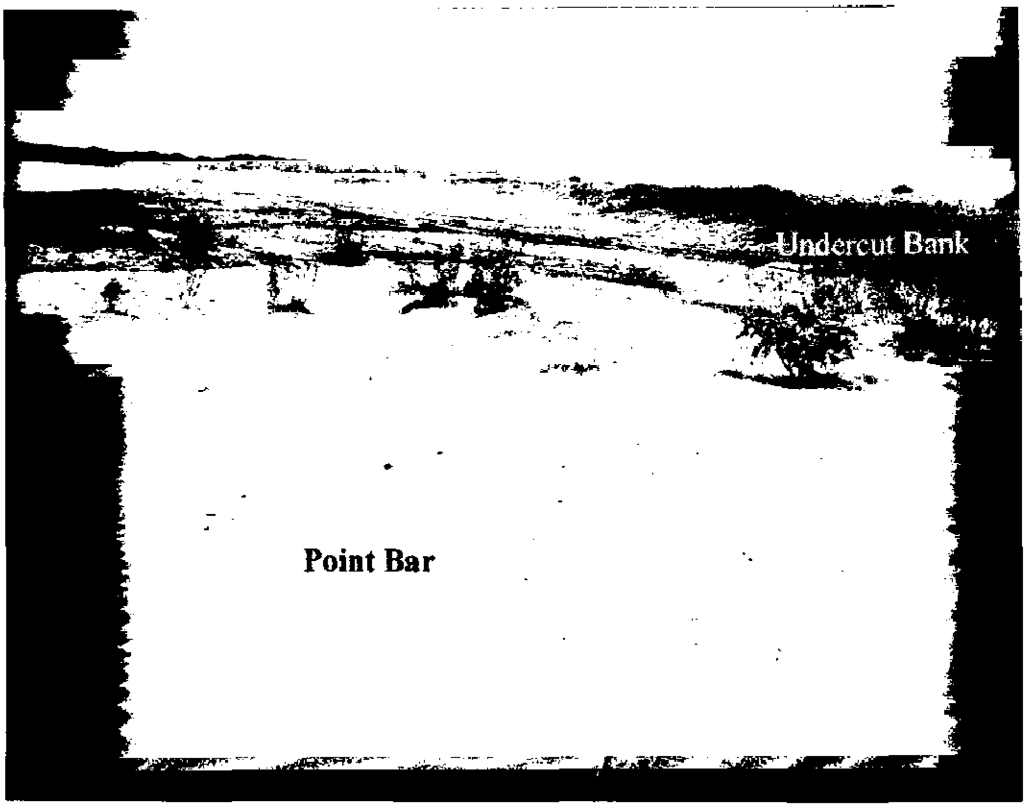


Fig. 1: Point Bar and Under Cut Bank of Chambal River, Ater, Bhind

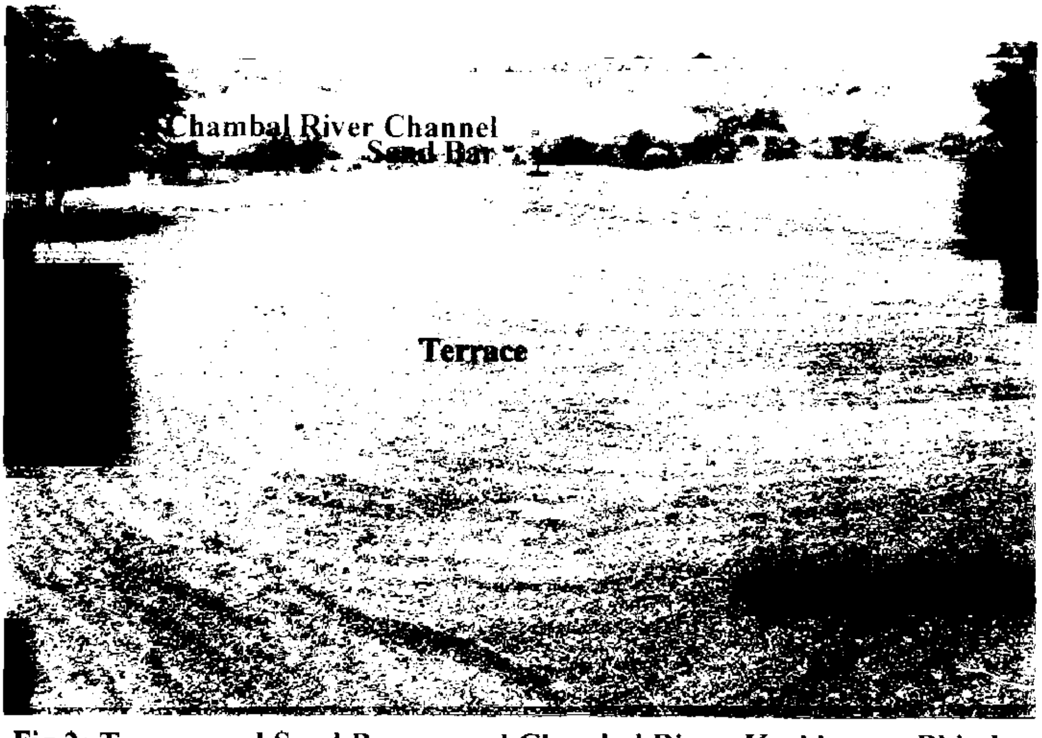


Fig.2: Terrace and Sand Bar around Chambal River, Kachhpura, Bhind

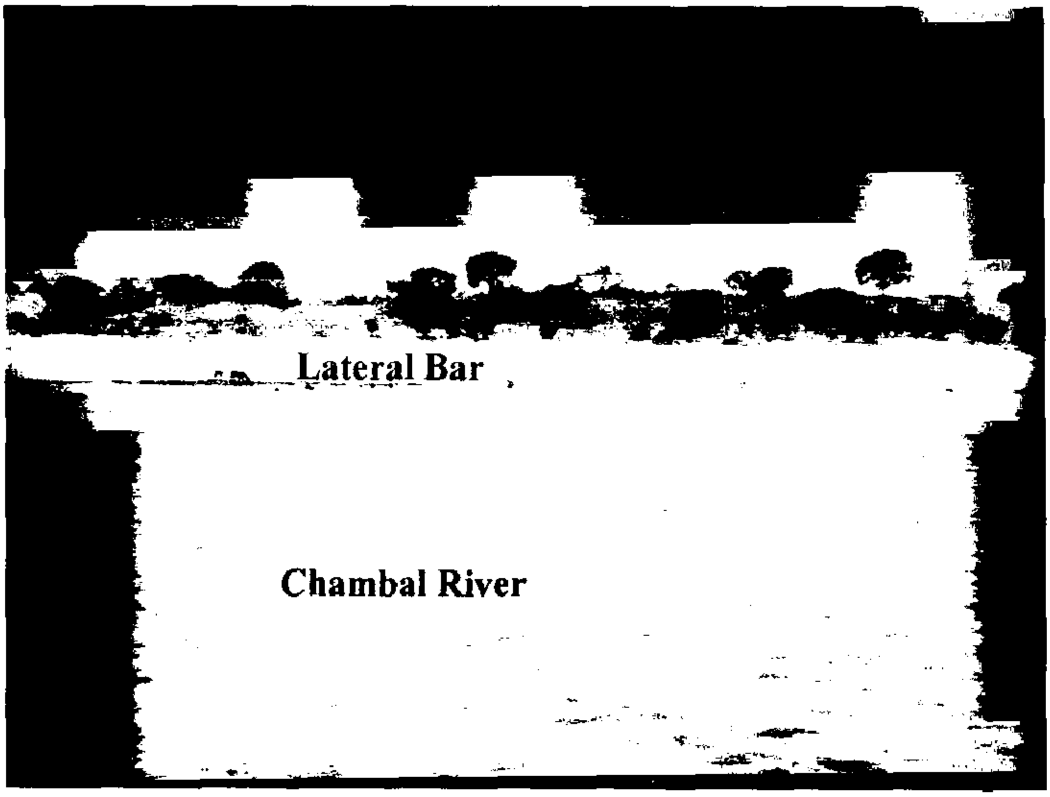


Fig. 1: Lateral Bar and Terrace zone, Chambal River, Bhind

Fig.2: Tear drop shape longitudinal Bar within Kunwari River, Morena

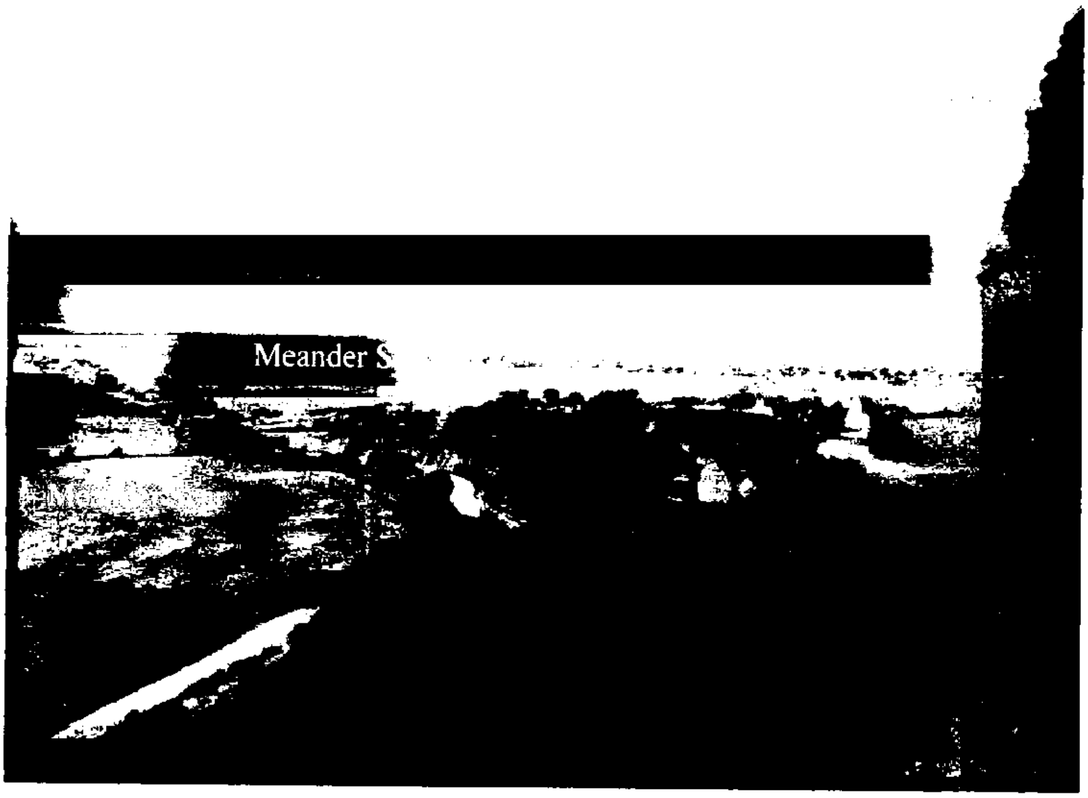


Fig. 1: Incised Meander scar near Ater Fort, Bhind

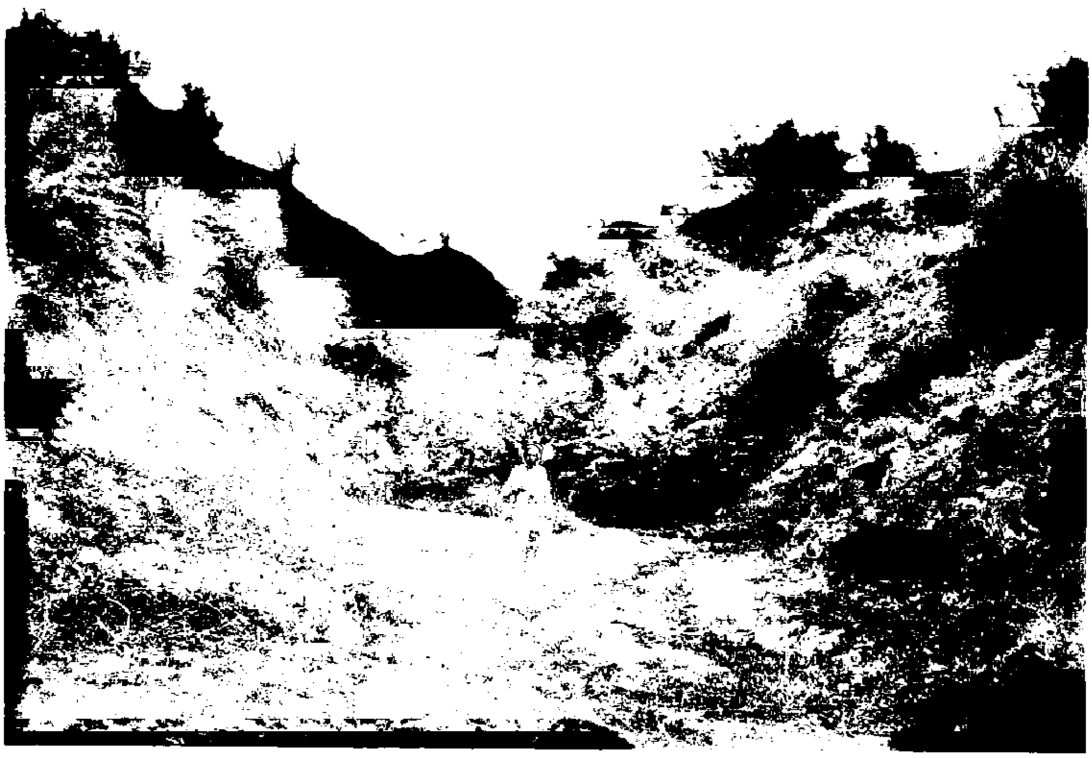


Fig. 2: V- Shaped ravines, Ater, Bhind

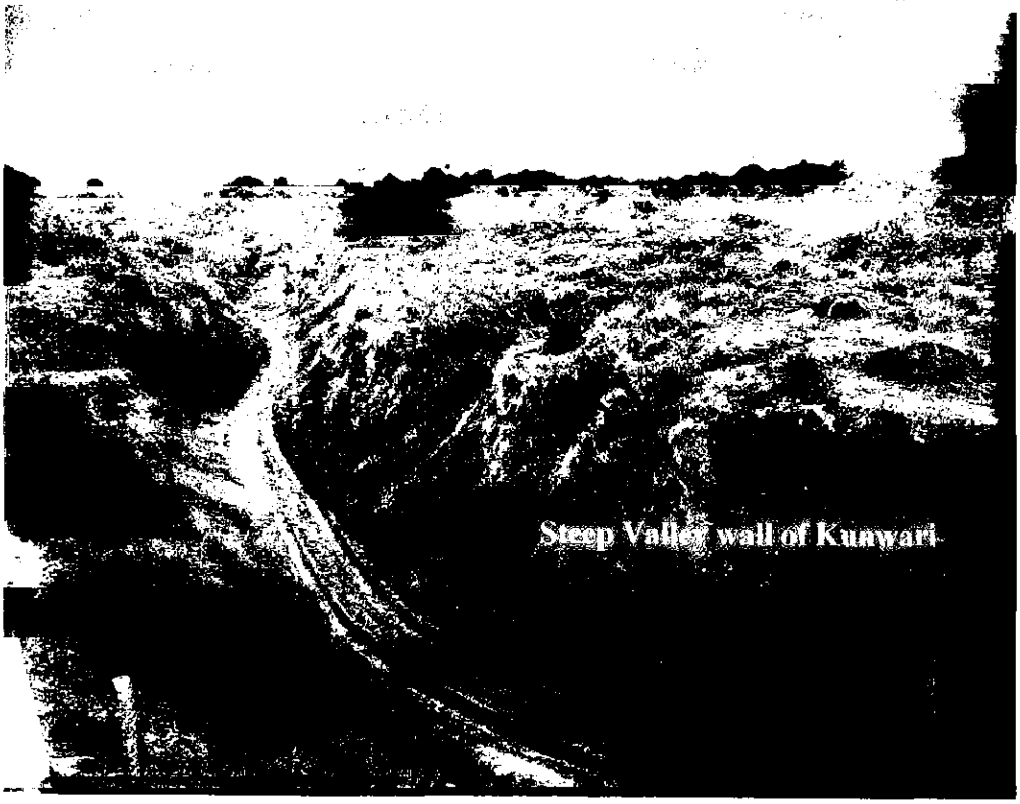


Fig. 1: Valley formed due to down cutting by streams of Kunwari River, Morena

Fig. 2: Valley formed due to down cutting by streams of Chambal River, Bhind

Plate-IX

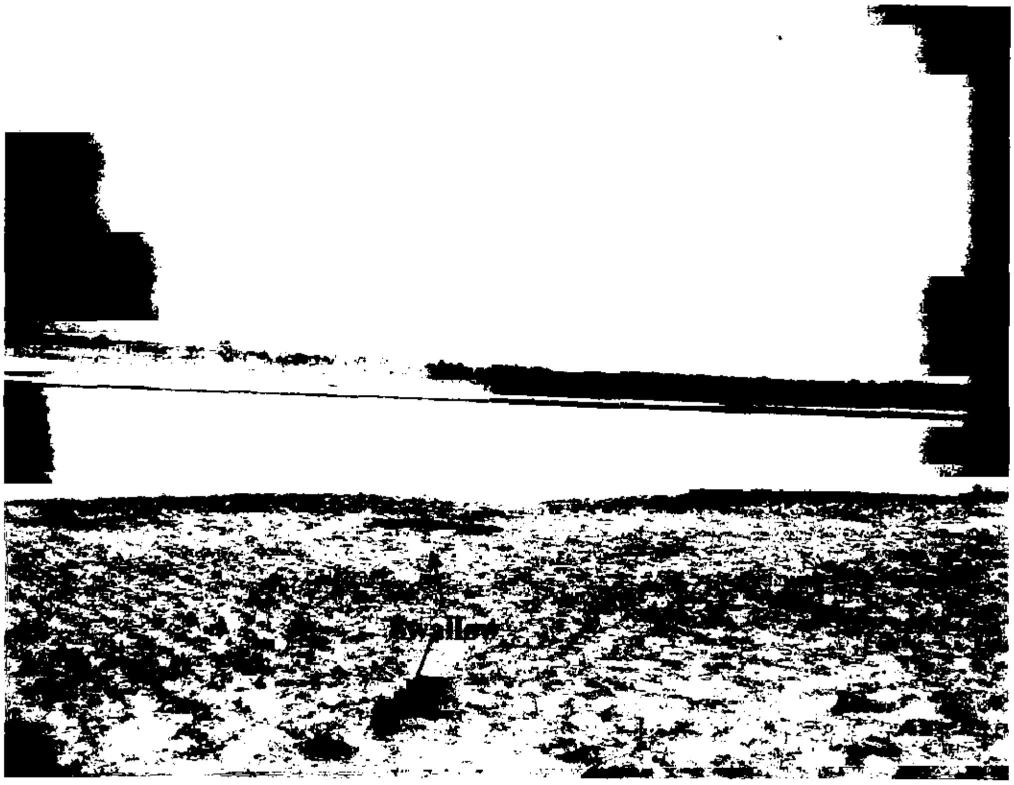


Fig. 1: Shallow- Swallow hole stage of ravine development, Ater, Bhind,

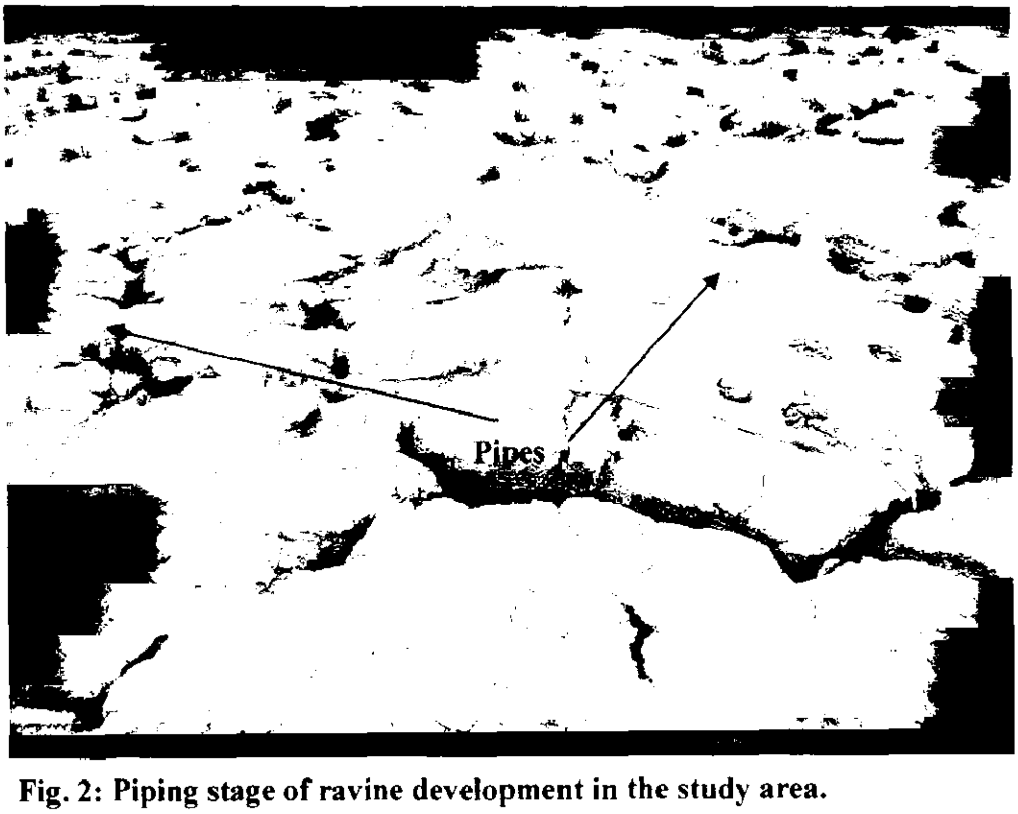


Fig. 2: Piping stage of ravine development in the study area.

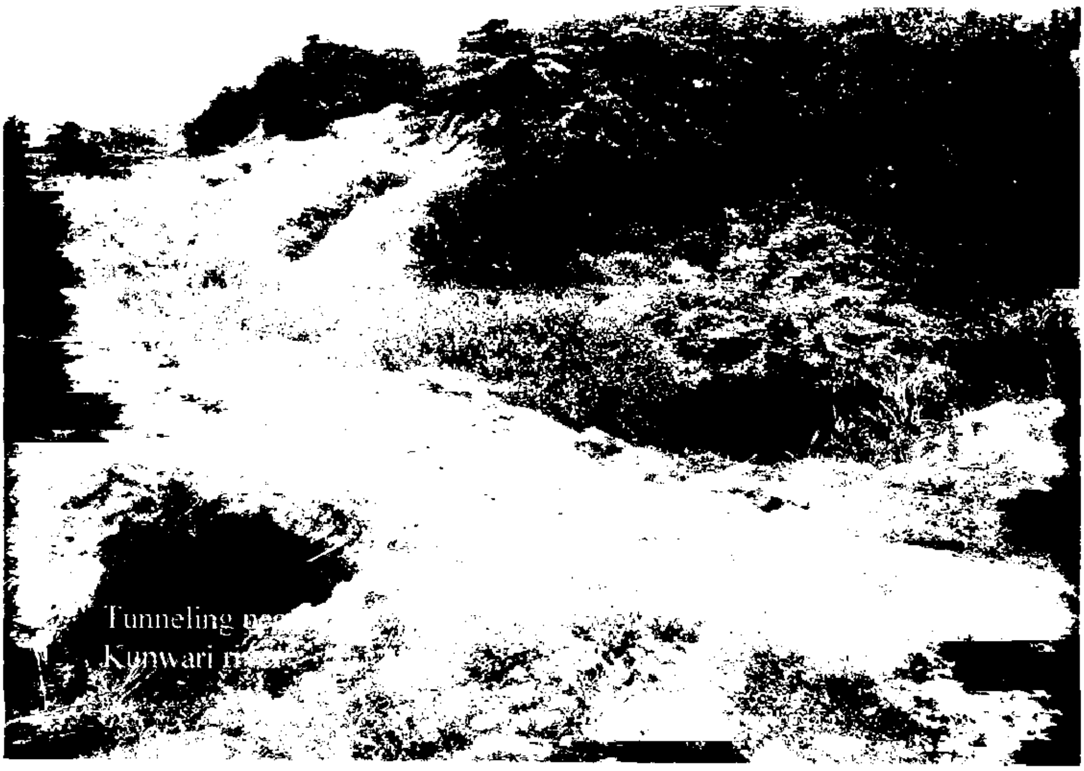


Fig.1: Tunnel resulting from sub-surface removal of material near Kunwari river, Chhounda, Bhind.

Fig. 2: Expansion of ravines by slumping, Bhind

Fig. 1: Bulbous Ravine of Kunwari, Rohinda, Bhind

Fig. 2: Compound Ravine of Chambal near Nawali Brindawan, Bhind

Fig. 1: Densely Vegetated Chambal ravines, Ater, Bhind

Fig. 2: Gulling within Chambal ravine and initiation of new cycle of erosion

Fig. 1: Splintery Shale layer within alluvium

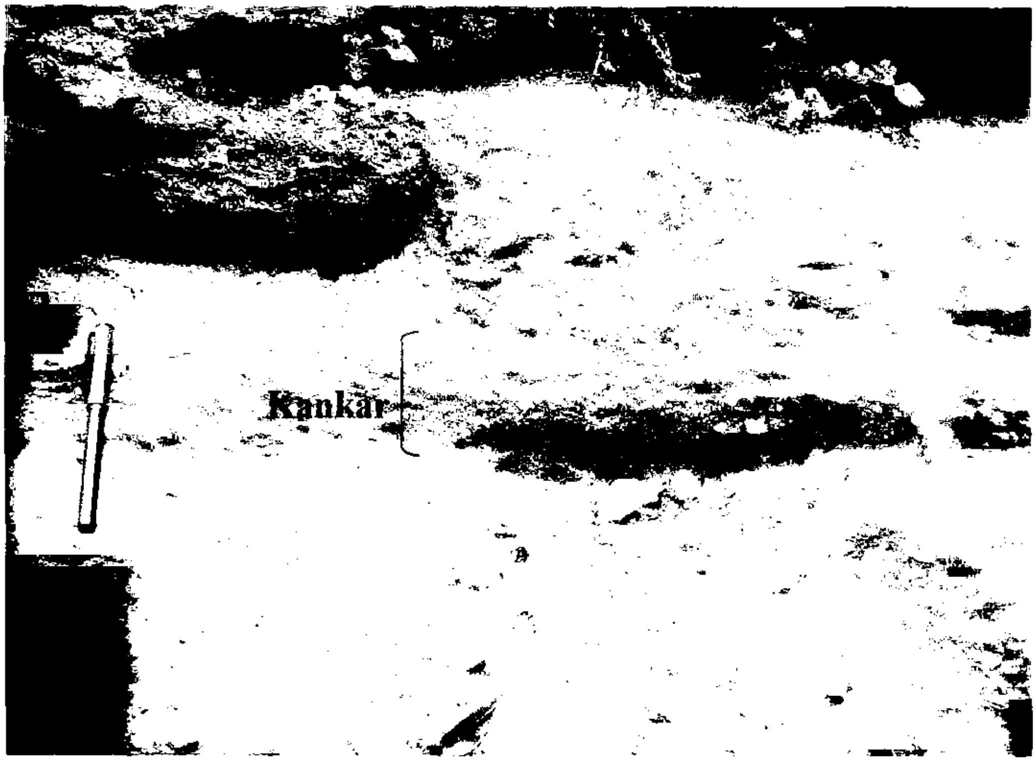


Fig.2: Kankar layer within Older Alluvium found in valley cut of Chambal, Nagra Porsa, Morena

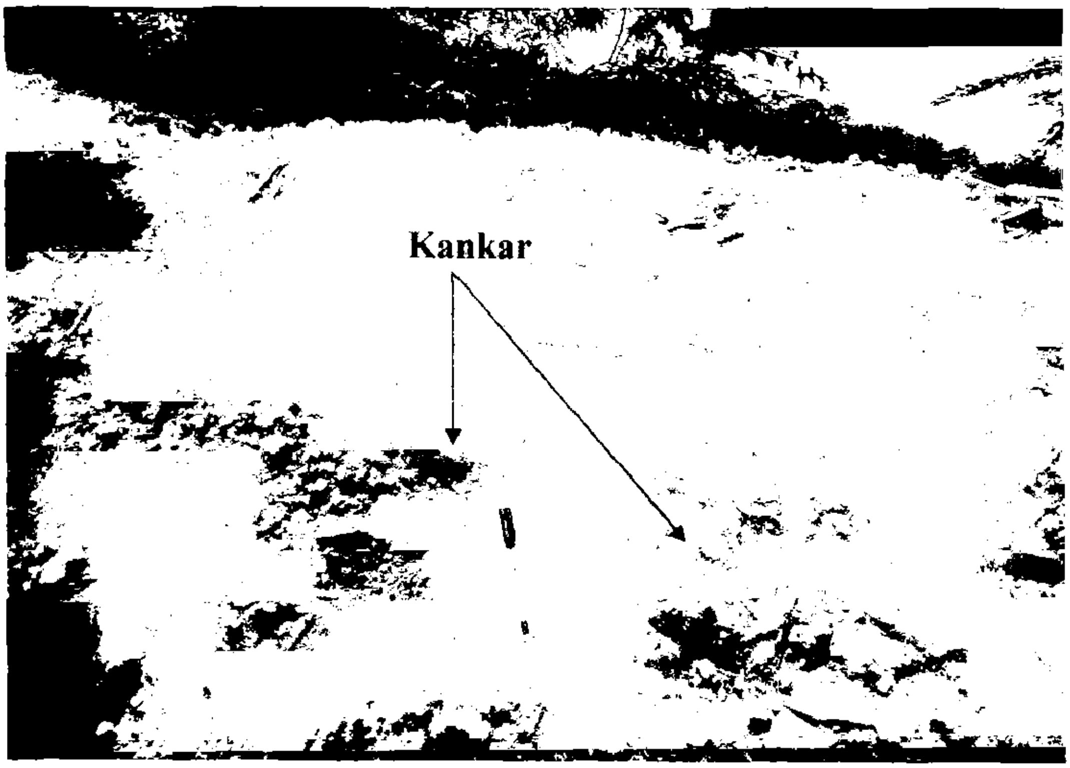
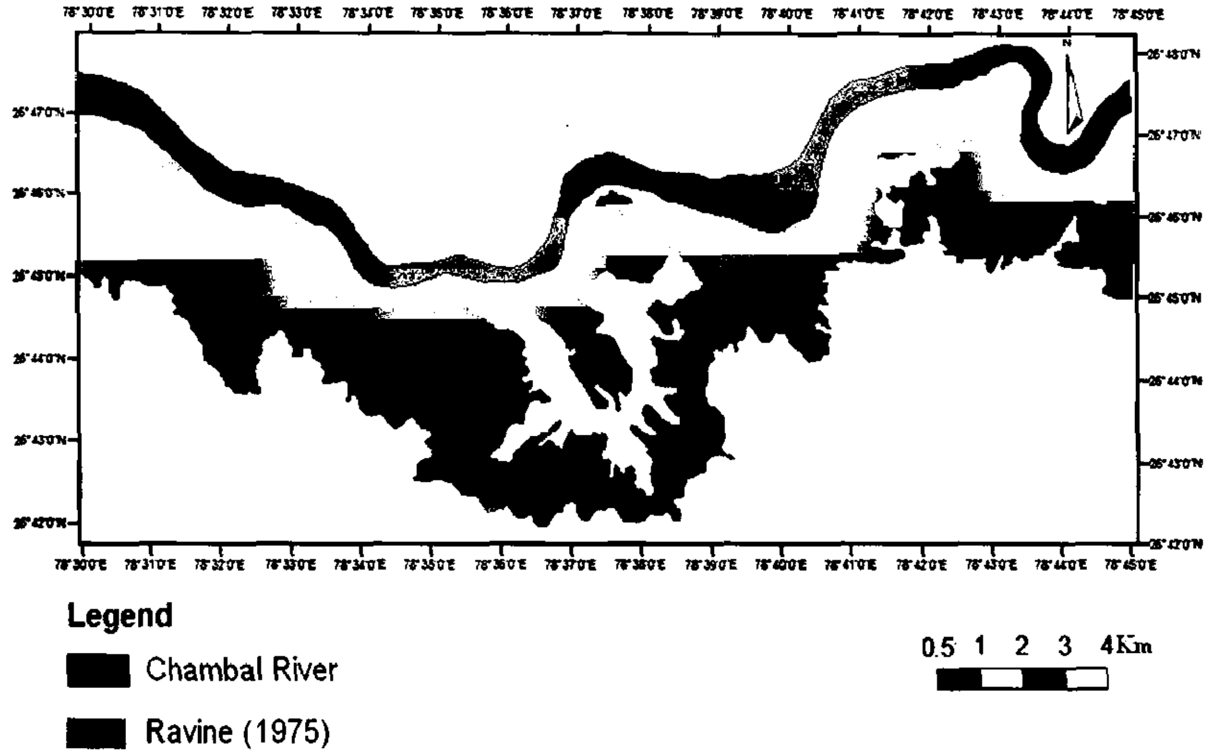


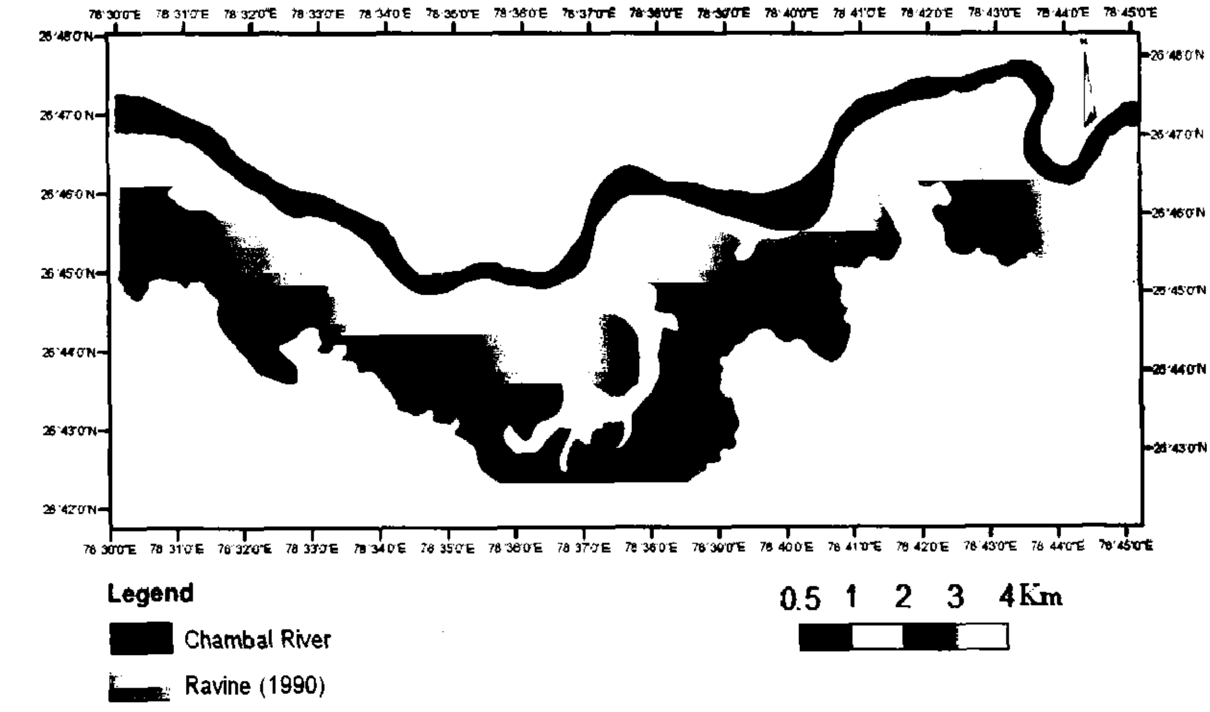
Fig.1: Kankar in river valley of Kunwari

Fig. 2: Weathered Shale showing meander plug, Near Ater,Chambel

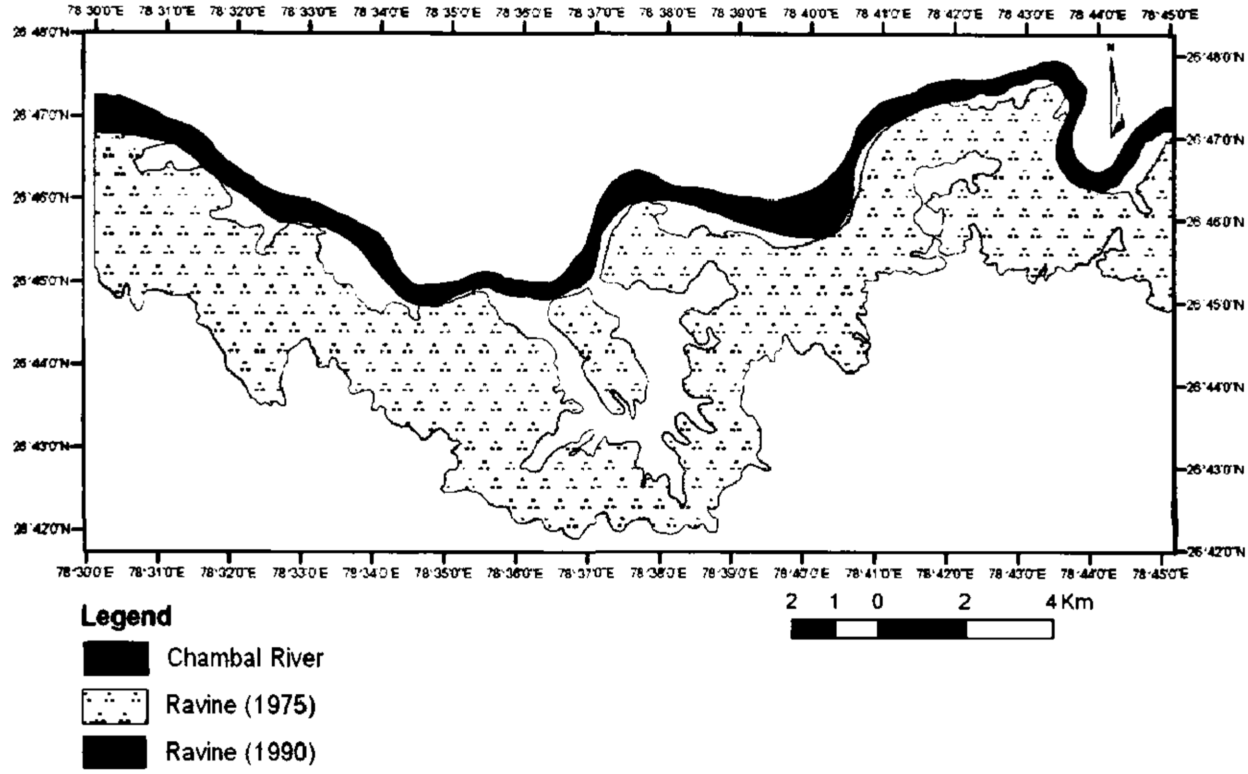
Annexures



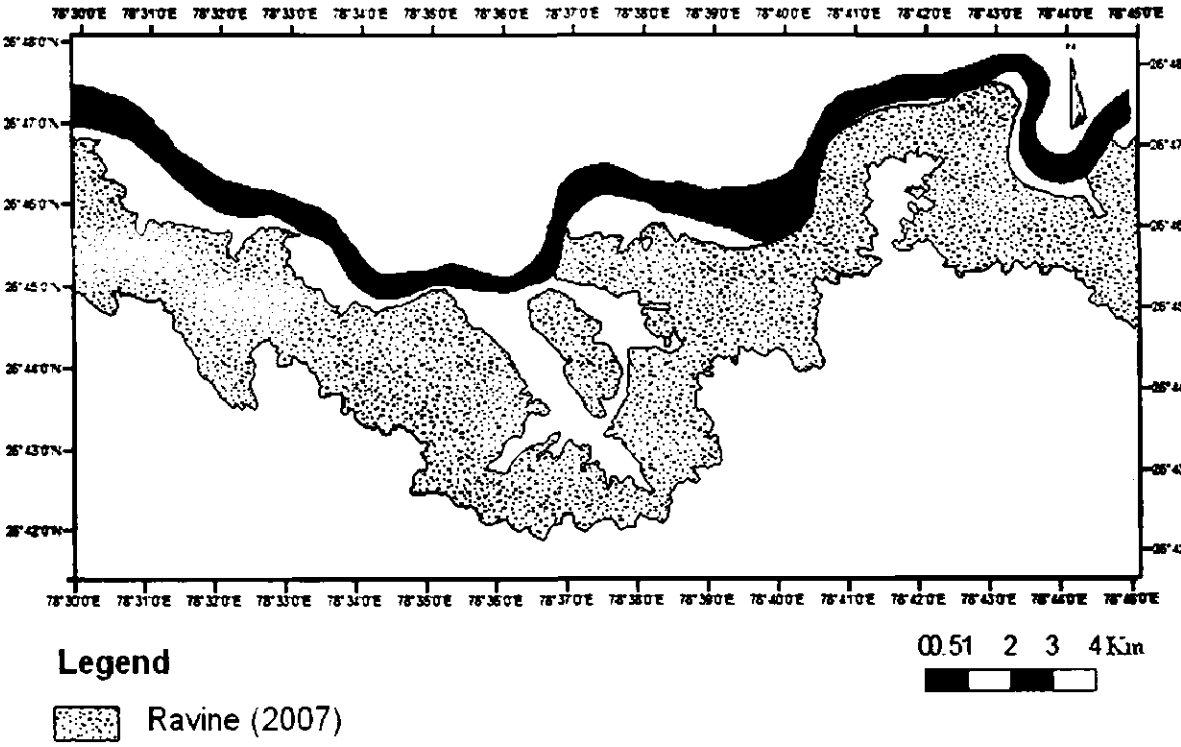
Annexure: 6.1. Chambal Ravines in year 1975



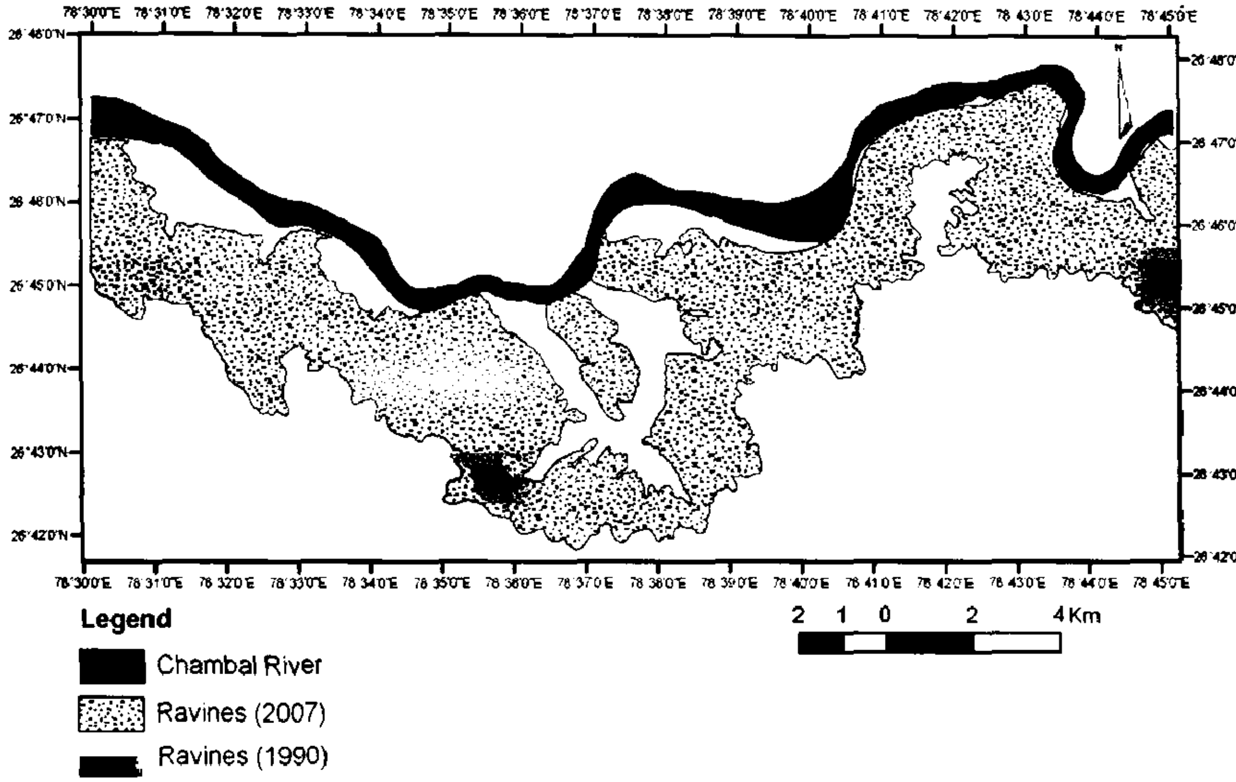
Annexure: 6.2. Chambal Ravines in year 1990



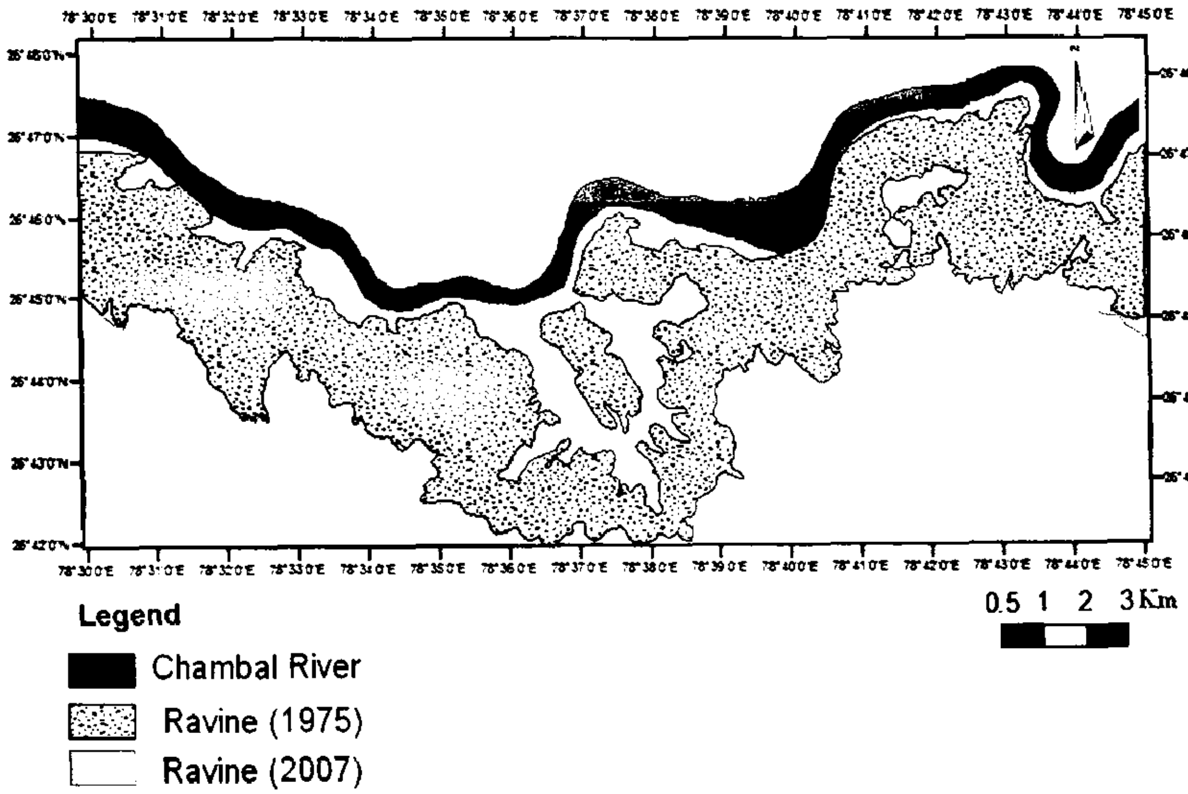
Annexure: 6.4. Overlay map Chambal Ravines of year 1975 and 1990



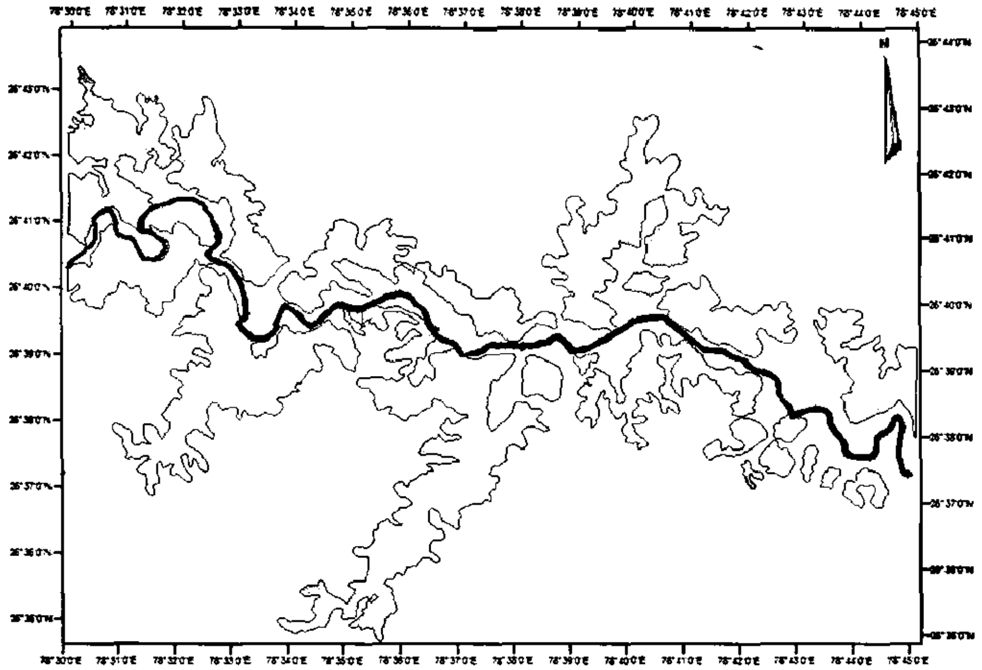
Annexure: 6.3 Chambal Ravines in year 2007



Annexure: 6.5 Overlay map Chambal Ravines of year 1990 and 2007



Annexure: 6.6 Overlay map Chambal Ravines of year 1975 and 2007



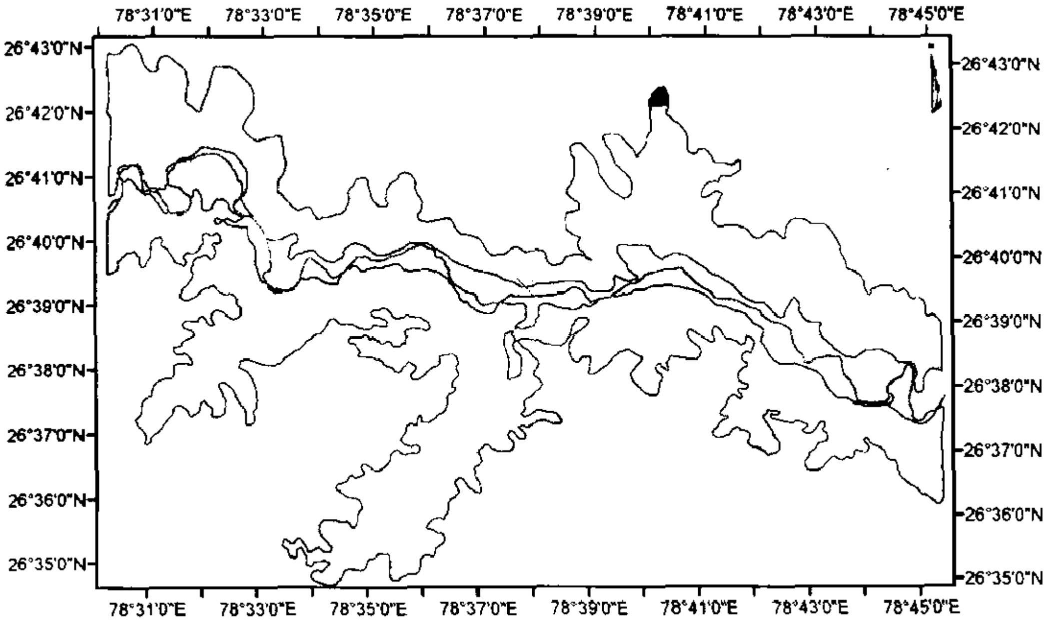
Legend

Kunwari River

Ravine (1975)

0.5 1 2 3 4Km

Annexure: 6.7 Kunwari Ravines in year 1975



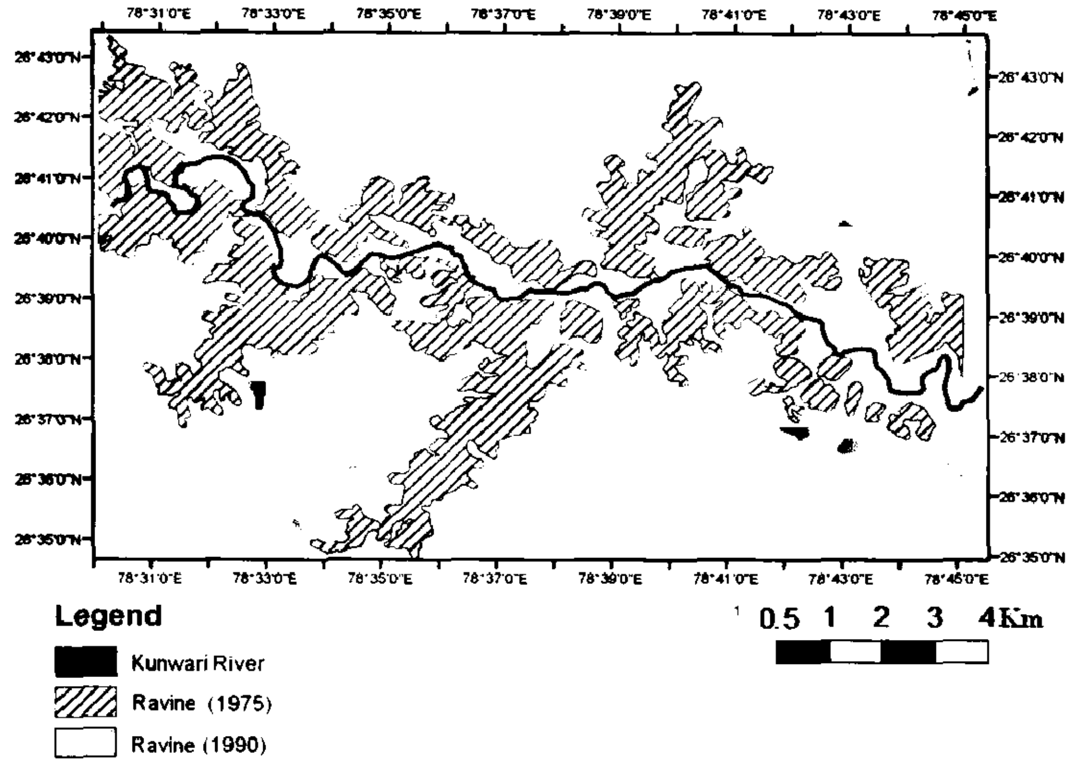
Legend

Kunwari River

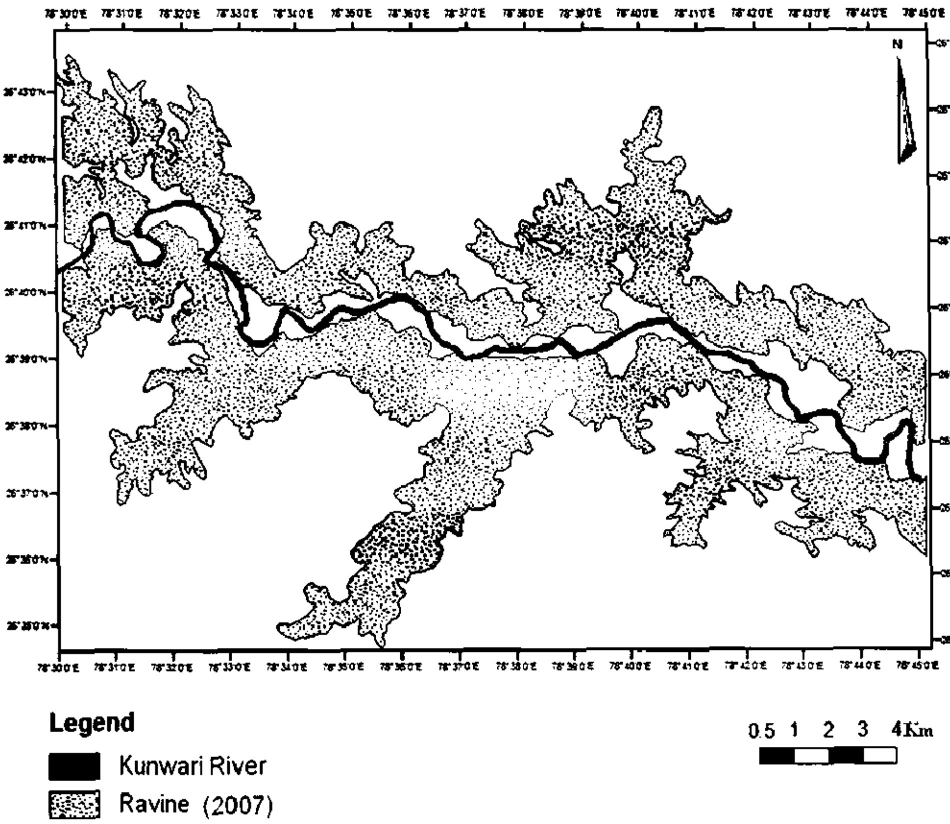
Ravine (1990)

2 1 0 2 4 6Km

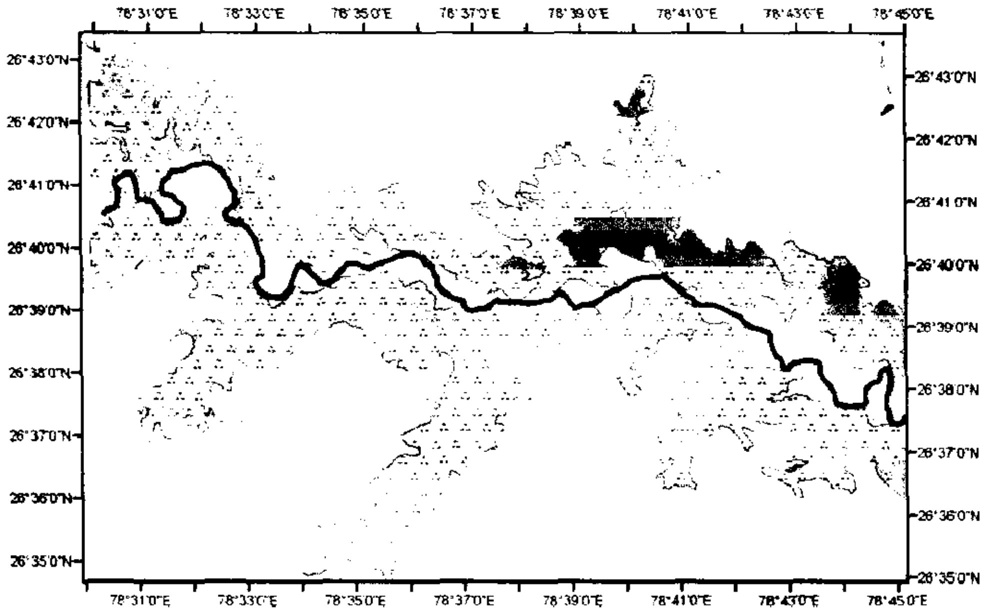
Annexure: 6.8 Kunwari Ravines in year 1990



Annexure: 6.9. Overlay map Kunwari Ravines of year 1975 and 1990



Annexure: 6.10. Kunwari Ravines in year 2007



Legend

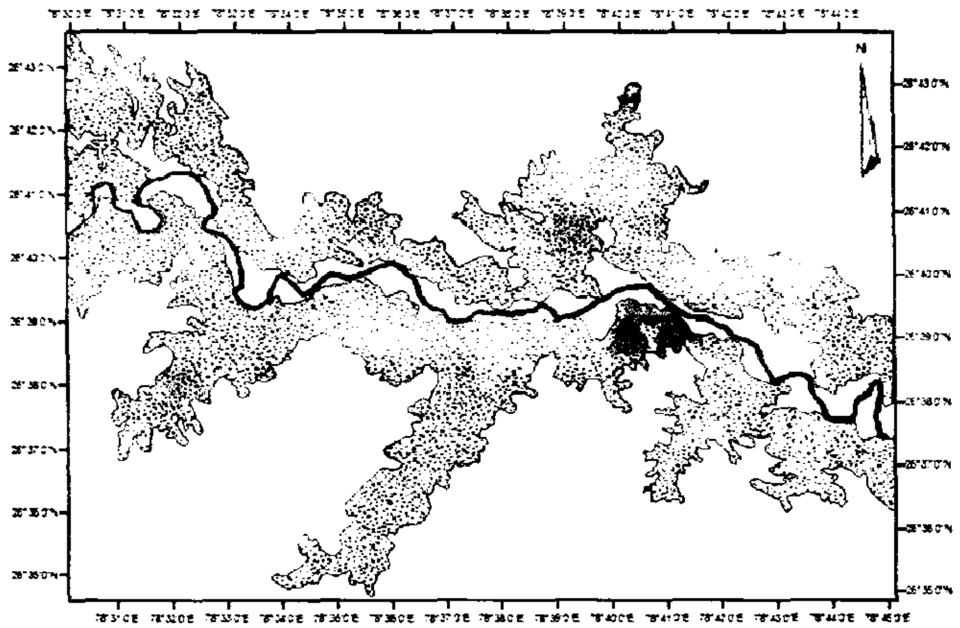
0.5 1 2 3 4Km

Kunwari River

Ravine (1990)

Ravine (2007)

Annexure: 6.11. Overlay map Kunwari Ravines of year 1990 and 2007



Legend

0.5 1 2 3 4Km

Kunwari River

Ravine (2007)

Ravine (1975)

Annexure: 6.12. Overlay map Kunwari Ravines of year 1975 and 2007

List of Publications

PUBLICATIONS (International/National)

1. Rao, L. A. K., Ansari, Z.R., Sadique, M. and **Yusuf, A.** (2013). Morphometric Analysis Of Four Sub-Watersheds In Bah Area Of Agra District Using Remote Sensing And GIS Techniques. Jour. Geol. Soc. India. (**Accepted**).
2. Rao, L. A. K. and **Yusuf, A.** (2013). Morphomertic Analysis for Soil Erosion Assessment in Parts of Chambal Basin using Remote Sensing and GIS, Madhya Pradesh. International Journal of Advanced Technology & Engineering Research. V.3 (3), pp.134-141.
3. Ansari, Z.R., Rao, L.A.K. and **Yusuf, A.** (2012). GIS based Morphometric Analysis of Yamuna Drainage Network, in parts of Fatehabad area of Agra District, U.P, India. Jour. Geol. Soc. India, v.79, pp.505-514.
4. Rao, L. A. K., Ansari, Z.R., Sadique, M. and **Yusuf, A.** (2012). Morphometric Analysis of four sub-watersheds in Bah area of Agra district using Remote Sensing and GIS Techniques Environment Climate Change and Sustainable Development. Ed. Vinita Katiyar and S.K. Verma, Radha Publications.
5. Rao, L. A. K., **Yusuf, A.** and Ansari, Z.R., (2012). Application of Remote Sensing and GIS in Wasteland Mapping: A Case Study of Agra District, Utter Pradesh, India" Environment Climate Change and Sustainable Development. Ed. Vinita Katiyar and S.K. Verma, Radha Publications.
6. Rao, L. A. K., Ansari, Z.R. and **Yusuf, A.** (2011). Morphometric Analysis of Drainage Basin Using Remote Sensing and GIS Techniques: A Case Study of Etmadpur Tehsil, Agra District, U.P." International Journal of Research in Chemistry and Environment; 1 (2).
7. Rao, L. A. K., Ansari, Z.R., Khan, S., Sadique, M. and **Yusuf, A.** (2010) Geomorphologial studies in parts of Agra district, U.P., using Remote Sensing and GIS techniques. International Journal Ultra Scientist of Physical Sciences, 22(1):147-154.

PUBLICATIONS (Conference/Seminar)

1. Rao, L. A. K., **Yusuf, A.**, Ansari, Z.R. and Asadullah, I.M. (2012). Moonstone Occurance in Indwara area of Koderma, Jharkhand. Fourth National Seminar on Gemmology, March, 3-4, 2012.

2. Rao, L. A. K., Ansari, Z.R and **Yusuf, A** (2011) Role of Geological and Geomorphological Factors in Ground Water Exploration: A Study Using IRS LISS-III Data. 4th International Congress of Environmental Research. 15-17th Dec, 2011 Sardar Vallabhbhai National Institute of Technology, SURAT (Gujarat).

3. **Yusuf A**, Rao, L. A. K., Ansari, Z.R. and Khan, S. (2011) Application of Remote Sensing Studies in parts of Agra District, Uttar Pradesh. Proc. Of National Seminar on Water and Environment, Challenges for Water Resource Management in 21st Century.

4. Rao, L. A. K., Ansari, Z.R., Khan. S., Sadique, M., **Yusuf, A.** (2010) Lineament Study of Etmadpur area, Agra District of Uttar Pradesh, India. Proceedings of National workshop on Repair, Renovation and Restoration (RRR) of Water Bodies, CGWB, North Central Region, Ministry of Water Resources, Govt. of India, Bhopal, M.P. pp. 102-107.

MONOGRAPH

Rao, L. A. K., Ansari, Z.R. and **Yusuf, A.** (2012) Hydrogeomorphology of an Alluvial Plain: A Case Study of Agra District, India. Publisher: LAP LAMBERT Academic Publishing GmbH & Co.KG, Germany.

ABSTRACTS

1. Rao, L.A.K., Ansari, Z.R., and **Yusuf, A.** (2012).Remote Sensing and GIS application in hydrogeomorphological studies of Agra District, Uttar Pradesh, India. International Conference on Population, Dynamism and Sustainable Resource Development. 25th-27th March, 2012.Department of Geography, Aligarh Muslim University, Aligarh.

2. Ansari, Z.R., Rao, L.A.K. and **Yusuf, A.** (2011). Landuse/landcover study in part of Lesser Himalayan Region using Remote Sensing and GIS technique. National Conference on Population, Resource and Environment.1st-2nd March, 2011.Department of Geography, Aligarh Muslim University, Aligarh.

3. Rao, L.A.K., Ansari, Z.R., Sadique, M and **Yusuf A.** (2010). Geomorphological mapping in parts of Etmadpur, Agra district, U.P., using Remote Sensing and GIS techniques. Nat. Seminar. Geodynamics and mineral

resources of Proterozoic Basins of India held at Department of Geology & Geoinformatics and Earth Sciences, Yogi Vemana University, Kadapa, from Mar. 4th–6th, 2010.Ref: YVU/DGGE/GAMP2010/46.

4. Rao, L.A.K., **Yusuf, A.**, Ansari, Z.R., Sadique, M. (2010). Morphometric analysis of three sub-basins along Yamuna river in parts of Fatehabad area of Agra district, U.P., India. Nat. Seminar. Geodynamics and mineral resources of Proterozoic Basins of India held at Department of Geology & Geoinformatics and Earth Sciences, Yogi Vemana University, Kadapa, from Mar 4th–6th, 2010.Ref: YVU/DGGE/GAMP2010/47.

International Journal of Advanced Technology & Engineering Research (IJATER)
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MORPHOMERTIC ANALYSIS FOR SOIL EROSION ASSESSMENT IN PARTS OF CHAMBAL BASIN USING REMOTE SENSING AND GIS, MADHYA PRADESH

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Abstract

The area under investigation is a part of Chambal drainage basin falling in parts of Bhind and Morena district of Madhya Pradesh, severely affected by ravines and gully erosion. LISS-III data of IRS-P6 satellite has been used to delineate the drainage line and ASTER, 30m resolution data was used to delineate sub-watersheds and calculation of relief aspect with the help of SAGA 2.0.3 software's. The study area has been divided into 7 sub-watershed for computation of linear, areal and relief aspects of drainage basin while morphometric parameters were calculated using ArcGIS and ArcView software's. Morphometric parameters suggest the region to be covered by soft and unconsolidated surficial material overlaying impermeable subsurface. High drainage density and infiltration number suggest high surface runoff and relief aspect suggest highly rugged terrain which is due to presence of ravine and gullies in the study area.
Keywords: Chambal, ASTER, Morphometry, Ravines and Gully erosion.

Introduction

Morphometry is the measurement and mathematical analysis of the configuration of the earth's surface, shape and dimension of its landforms (Agarwal, 1998; Reddy et al., 2002) and morphometric parameters have been used for flood characteristics, sediment yield, basin evolution and other various geomorphology and surface-water hydrological studies (Jolly, 1982, Ogunkoya et al., 1984; Aryadike and Phil-Eze, 1989). The morphometric descriptors represent relatively simple approaches to describe basin attributes and find out their impact on the development of ravines in the areas of processes and to compare basin characteristics (Mesa, 2006) and enable an enhanced understanding of the geomorphic history of a drainage basin (Strahler, 1964).

Properties of the stream networks play a vital role to study the landform making processes and to understand the sub surface condition. Geographical Information System (GIS) techniques provide a favorable environment and a powerful tool for the analysis and depiction of spatial information (Srivastava and Mitra, 1997; Agarwal, 1998; Nag, 1998; Das and Mukherjee, 2005). The wide spread availability of elevation data in digital format has bolstered the development of automated tools that can be used to delineate drainage basin and their associated stream network. Maps prepared in the GIS environment is important from perspective point of view as the visual interpretation of calculated parameters for the 7 sub basins provides a better understanding of various drainage characteristic. The present study aims not only to analyze the morphometric attributes of Chambal river basin in parts of Bhind and Morena districts of Madhya Pradesh but to find out their impact on the development of ravines as yet no work has so far been carried out except delineation of ravenous and gullied land in lower Chambal valley by Pani and Mohapatra (2001).

A. Study Area

The study area is situated in the district of Bhind and Morena of Madhya Pradesh (Fig.1) and falls between 26^0 34' - 26^0 47'latitude and 78^0 30' – 78^0 45' longitude. The climate of study area may be characterized by a hot summer and general dryness except the monsoon season. The normal maximum temperature received during the month of May is 42.10^0 C and minimum during the month of January is 7.1^0C. Nearly one third of the Madhya Pradesh state area is covered with tropical forests ranging between the rivers Chambal in the north and Godavari in the south. To the east of Chambal, the area has rocky surface and thick forest. The main river systems are the Chambal, Betwa, Sindh, Narmada, Tapti, Mahanadi and Indravati that drain the state. In the study area Chambal is the main river and Kunwari is its tributary.

B. Geology

The oldest rock unit exposed in Bhind district belongs to the Gwaior Group of Palaeo-Meso Proterozoic age and classified into Singpur, Sitla, Sithauli and Braoli Formations. Some outcrops belonging to Vindhyan Super Group are exposed in the western parts of the district in Gohad tehsil. The Kaimur Group comprises of sandstone with minor shale bands is exposed in southwestern part of Bhind district. The rock unit belonging to Vindhyan to Vindhyan Supergroup, Laterites of Cenozoic age and Quarternary Alluvium are exposed in Morena district. Alluvium consists of clay, sand and gravels *occupies a major part of the district and its thickness varies* from 70 to 250m and resting over the Vindhyan rocks.

Methodology

IRS P-6 LISS-III data obtained in April 2006, corresponding to path row no 98-53 was used for tracing of drainage lines. The traced drainage map was digitized in ArcMap 9.3 interface of ArcGIS 9 version. ASTER (30m) data was downloaded and was clipped and exported as ASCII file format from SAGA software. Final elevation and slope map was prepared by ASCII file in ArcMAP. Detailed morphometric study is carried out and discussed with respect to Linear (b) Areal and (c) Relief aspects of the channel network and contributing ground slopes. Attribute table for different parameters were made and sub-watershed is classified according to the computed value into low, medium and high in ArcMAP 9.3.

Results and Discussion

A. Linear Aspects Of The Drainage Network

Stream Segments, and Stream Order (Nu): This is a section of stream channel between two channel junctions or, for "fingertip" tributaries, between a junction and the upstream termination of a channel. In the hierarchy of stream segments according to Straler (1954) ordering classification system, channel segments were ordered numerically from a stream's head waters to a point somewhere downstream. The streams show branching in all directions and characterized by dendritic pattern of development (Fig.1). it is observed that tha number of stream segment of any order is fewer than the next lower order but more numerous than the next higher order. This observation verifies the Horton's Law of stream number (1945). In sub-watersheds CH-II, KW-III and KW IV has more than 250 (Table1) which indicates that the lithology to be soft and high dissection in these watershed. CH-II is the only sub watershed with one Vth order and three IVth order stream joins, which suggests the unconsolidated nature of alluvium cover in CH-II.

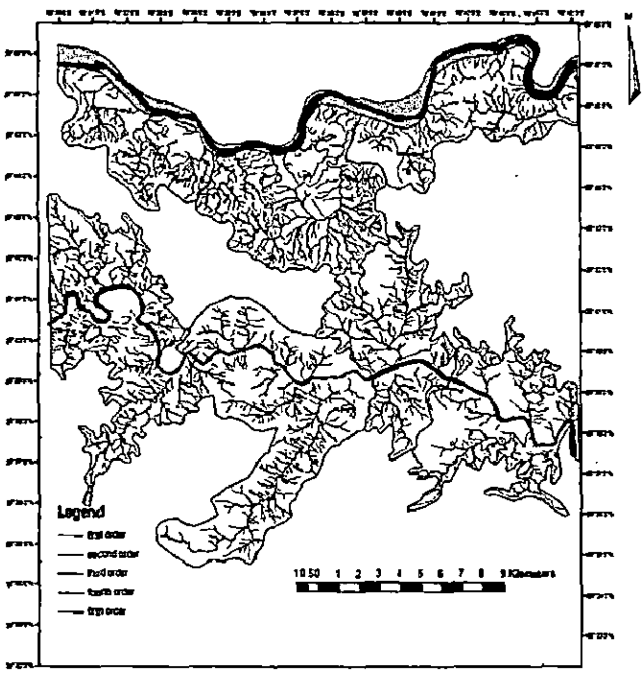

Figure 1: Drainage Map of the Study area

Bifurcation Ratio (Rb): The frequency with which streams of certain order flow into those of next higher order is refer to as bifurcation ratio. Schumm, (1956) and Horton (1945) considered it as index of relief and dissection. The risk factor of flood is indirectly related with the bifurcation ratio by Waugh (1996). Slope of best fitted line of Semi log plots of stream order vs Stream number (Fig.2) gives the bifurcation ratio. It has been found that the bifurcation ratios characteristically range between 3.0 to 5.0 for watersheds in which geology is reasonably homogeneous or geological structure do not disturb pattern (CGWB.1982) area with uniform surficial materials where geology is reasonably homogeneous and the drainage patterns have not been distorted because of structural disturbances (Strahler, 1964). This may also be attested to presence of very reasonably homogeneous and the drainage pattern has not been distorted because of structural disturbances (Strahler, 1964). This also be attested to presence of very thick alluvium cover over Vindhyan Basement. However in sub watershed KW-III and IV the values are slightly above 5 ie, 5.23 and 5.40 (Fig.3) respectively which shows that the structure have little control over drainage development in these sub-watershed. High Rb values indicate structural control of drainage and also signify streams that have a higher average flood potential because numerous tributary segments drain into relatively few trunk transporting stream segments.

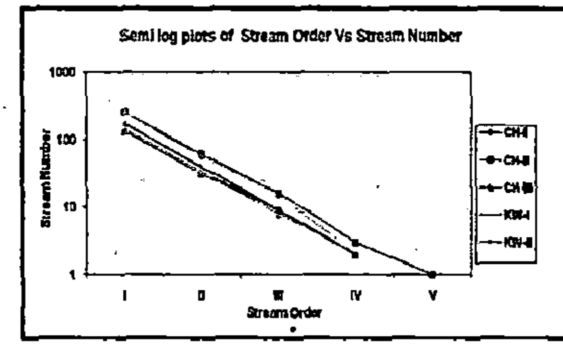

Figure2: Graphical representation of Streams order and Stream number

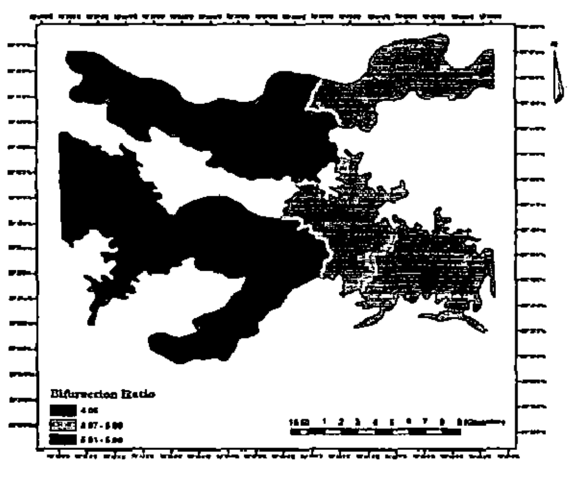

Figure 3: Bifurcation Ratio classification

Table:1 Stream Number and Bifurcation Ratio

Stream Order	CH - I		CH - II		CH -III		KW-I		KW-II		KW-III		KW-IV	
	Nu	Rb	Nu	Rb	Nu	Rb	Nu	Rb	Nu	Rb	Nu	Rb	Nu	Rb
I	135	4.2	251	4.04	136	4.25	143	4.2	172	4.3	250	4.46	252	3.5
II	32	3.55	62	3.87	32	4	34	3.7	40	4.44	56	3.73	71	3.9
III	9	4.5	16	5.33	8	4	9	4.5	9	4.5	15	7.5	18	9
IV	2		3	3	2		2		2		2		2	
V			1											

Dendritic drainage basin has bifurcation ratio range 3.5-4 while that of trellis pattern had much higher value. In the present area of investigation, the mean Rb value ranges between 4.06 and 5.4 which is slightly higher than the range mentioned above indicates that the drainage basin has dendritic to sub-dendritic pattern.

Stream Length (Lu) and Stream Length Ratio (Rl): It is the length of stream of various orders from their mouth to drainage divide. The stream length has been computed based on law proposed by Horton (1945). Usually the total length of stream segment is maximum in first order and decreases as the stream order increases. This trend is followed in all sub-watersheds except CH-III where length of third order stream is 7.27 km and that of fourth order stream are 7.73km (Fig.4). This may be attributed to change in this may be attributed to change in rock type, moderately steep slope and probable upliftment across the watershed (Singh and Singh, 1997, Vittala et al 2004).

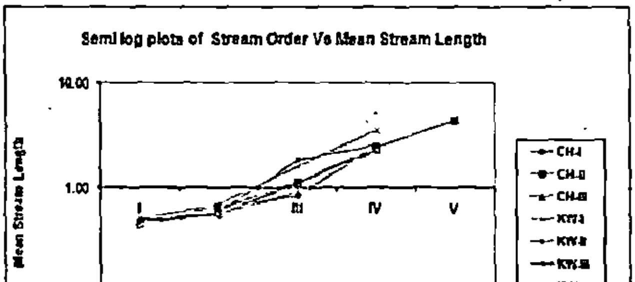

Figure.4: Graphical representation of Stream order and stream length

Mean length of a stream channel segment of order 'U' is a dimensional property, revealing the characteristic size of component of drainage network and its contributing basin surface (Strahler, 1964). Mean stream length for lower order is less than its next higher order in all the sub-watersheds. In the study area value of stream length varies from 0.44 – 5.1 km. Stream Length ratio have important relationship with the surface flow discharge and erosional stage of the basin (Sreedevi et,al, 2009). CH-I, III and KW-IV show increasing trend (Table.2) of length ratio from lower to higher order indicating mature geomorphic stage of development whereas all other sub-watershed show variation in values suggesting late youth stage of geomorphic development (Singh and Singh, 1997, Vittala et al 2004).

B. Aerial Aspects of the Drainage Network

Basin Area (Au):

A drainage basin is an area defined by a topographic boundary that diverts all runoff to a single outlet and separates runoff between two basins is the drainage divide. Basin area is also defined as the area which is drained by stream or a system of streams in such a way that all stream flow originating within the basin parameter discharges through a single outlet. Total area of the watershed is 183 km^2. Among the sub-watershed maximum drainage area is covered by the sub watershed -I whereas sub watershed – IV occupy minimum drainage area (Table:3).

Basin Shape (Bs):

The shape of the basin is a very important factor in determining discharge characteristics of streams and may considerably affect stream flow hydrograph and peak flow. There are various parameters which are used to define the shape of the basin including Elongation Ratio (Re), Form Factor (Rf), Circularity Ratio (Rc).

Schumm, (1956) defined elongation ratio as the ratio of diameter of a circle of the same area as the basin to the maximum basin length. Value near to 1 is typical of region of very low relief, whereas the values in the range of 0.6 to 0.8 are generally associated with strong relief and steep ground slope. The area with high value of elongation ratio has high infiltration capacity and low runoff. However in the study area the values range from 0.12 to 0.23 (Table.3, Fig.5) which is very low indicating low infiltration and high runoff. Such basins are susceptible to high erosion and sedimentation load (Gangalakunta et. al, 2004).

Meller (1953) defined circulatory ratio is defined as the ratio of basin area, Au to the area of a circle Ac, having the same perimeter as the basin. In the study area circularity ratio ranges from 0.14 to 0.50 (Table-3). This shows that only sub-watershed CH-II having value of 0.50 is more or less circular while all the other sub-watersheds are of elongated shape, KW-I being most elongated (Fig.6).

Stream Order	CH - I			CH - II			CH – III			KW - I			KW- II			KW - III			KW- IV		
	SL (Km)	MSL (Km)	SLR	SL (Km)	MSL (Km)	SLR	SL (Km)	MSL (Km)	SLR	SL (Km)	MSL (Km)	SLR	SL (Km)	MSL (Km)	SLR	SL (Km)	MSL (Km)	SLR	SL (Km)	MSL (Km)	SLR
I	67.43	0.49	0.45	111.84	0.44	0.60	60.06	0.44	0.63	71.81	0.50	0.49	81.33	0.47	0.30	107.76	0.43	0.41	112.59	0.44	0.54
II	17.66	0.55	0.57	39.24	0.63	0.40	18.32	0.56	0.39	23.79	0.69	0.60	23.23	0.58	0.71	37.82	0.67	0.32	40.00	0.56	0.47
III	10.11	1.12	0.26	17.84	1.11	0.45	7.27	0.90	0.30	14.31	1.59	0.33	16.62	1.84	0.28	12.40	0.82	0.35	18.84	1.04	0.35
IV	4.62	2.31		7.27	2.42	0.35	4.62	2.31		7.14	3.57		5.10	2.55		5.11	2.55		10.20	5.1	
V				4.43	4.43																

Table –2: Stream Length, Mean Stream Length and Stream Length Ratio

S.No	Name of Basin	Basin Area (Km^2)	Perimeter (km)	Max Basin Length (km)	Elongation Ratio (Re)	Circularity Ratio (Rc)	Form Factor (Rf)
1	CH - I	130.50	35.57	8.95	0.20	0.31	0.39
2	CH-II	116.50	33.28	9.47	0.22	0.50	0.49
3	CH-III	30.00	25.23	8.65	0.18	0.48	0.32
4	KW-I	39.61	58.7	8.61	0.23	0.14	0.53
5	KW-II	34.89	49.07	10.49	0.18	0.18	0.31
6	KW-III	62.61	47.05	12.64	0.12	0.35	0.39
7	KW-IV	52.02	55.56	12.14	0.19	0.21	0.35

Table: 3 Shape Parameters

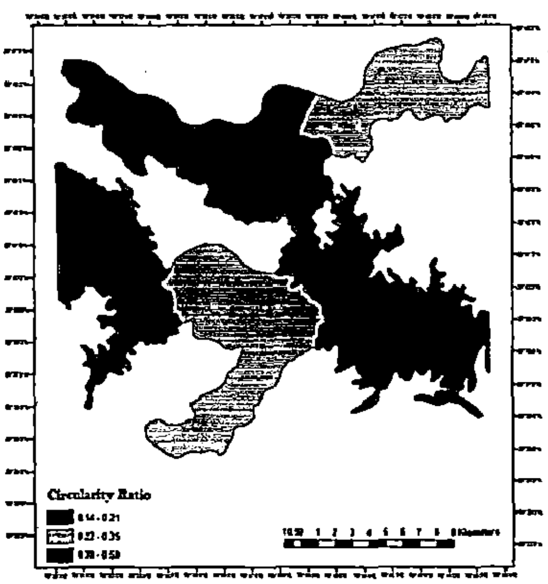

Figure 5: Elongation Ratio classification

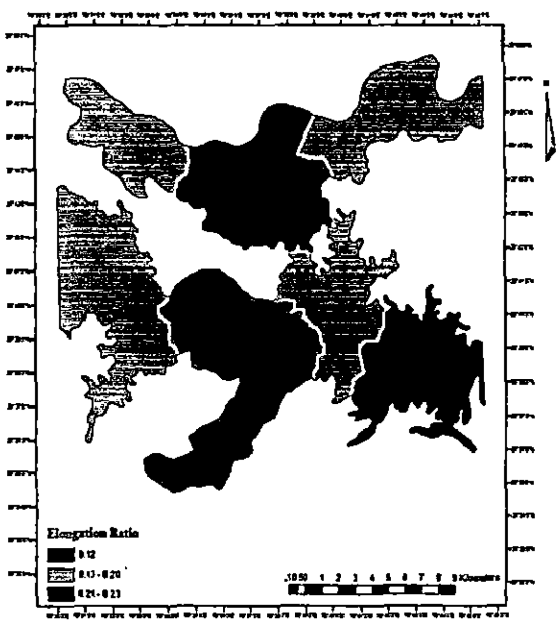

Figure 6: Circularity Ration classification

Horton (1945) proposed this parameter to predict the flow intensity of a basin having a definite area. Sub-basin having low form factor value ranging from 0.31 in sub-watershed KW-II to 0.53 in KW-I (Table-4, Fig.7) this suggest that all the basins falls in elongated basin category. A perfectly circular basin have form factor value >0.78. KW-I tends to be elongated but low form factor value. Such basins have a flatter peak of flow for longer duration (Sharkh, 2009). Flood flow for such basins is easier to manage.

S.No.	Name of the Basin	Drainage Density (Dd)	Stream Frequency (Fs)	Constant of Channel Maintenance (C)	Length of Overland flow (Lg)	Drainage Texture (Rt)	Infiltration No
1	CH-I	3.17	5.66	0.31	0.15	5.00	15.85
2	CH-II	4	7.47	0.25	0.12	10.00	40.00
3	CH-III	4.36	3.2	0.22	0.11	7.04	30.69
4	KW-I	2.95	4.7	0.33	0.16	5.12	15.10
5	KW-II	3.61	6.39	0.27	0.13	4.50	16.24
6	KW-III	2.6	5.1	0.38	0.19	6.56	17.83
7	KW-IV	3.4	6.5	0.29	0.14	6.17	20.97

Table4: Drainage Density, Stream Frequency, Drainage, Texture, Infiltration Number and Length of Overland Flow

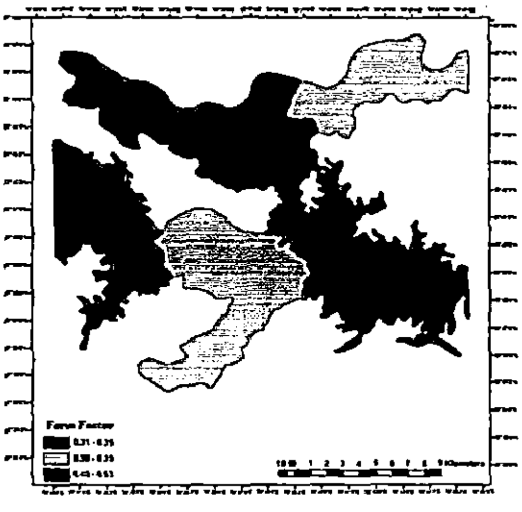

Figure 7: Form Factor classification

Horton (1932) defined *stream frequency* as the number of stream segment per unit area. The present study indicates, that the values of Fs range from 3.20 to 7.47 (Table-5) which is quite high. CH-II has the highest value (4.36) of drainage density but lowest stream frequency value (3.20) while that of CH-II sub watersheds has correlation with drainage density as it has both high drainage density and stream frequency value ie., 4 and 7.46 respectively (Fig.8 and Fig.9). Both measures reflect the degree of dissection of the landscape. High values of these parameters tend to develop in area with erodible soil and rock and high intensity rainfall. Fs values for these sub-basins are widely variable. KW-III has the lowest value (2.60) of drainage density but the drainage frequency is high (5.1). These variations may have found due to disproportionate increase in length of streams in relation to stream number where stream segment decreases vary greatly and is no longer proportionate with river length (Zavoianu, 1985). Stream length also increases because of the higher sinuosity of streams resulting in higher drainage density. Graphical representation of shape factors shows highest value of these parameter is obtain in CH-II (fig 9)

Name of Basin	Elevation		Max. Basin Relief (km)	Relief Ratio	Relative Relief (Rhp)	Ruggedness Number (HD)
	Source point (m)	End Point (m)				
CH-I	160	106	0.054	0.005	0.15	0.17118
CH-II	159	120	0.039	0.004	0.12	0.156
CH-III	160	112	0.048	0.005	0.19	0.20928
KW-I	157	125	0.032	0.003	0.05	0.0944
KW-II	158	124	0.034	0.003	0.07	0.12274
KW-III	163	125	0.038	0.003	0.08	0.0958
KW-IV	162	128	0.034	0.002	0.06	0.1155

Table: 5. Elevation Parameters

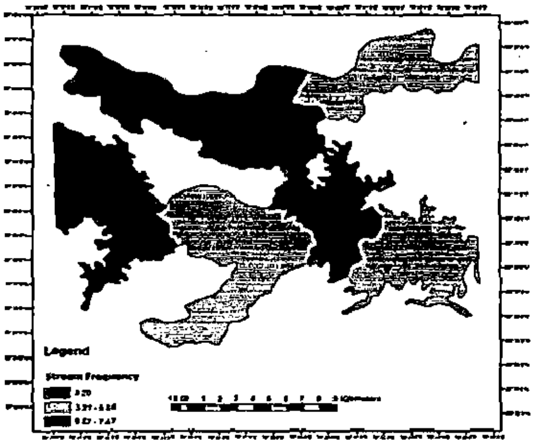

Figure 8: Classification of Stream frequency

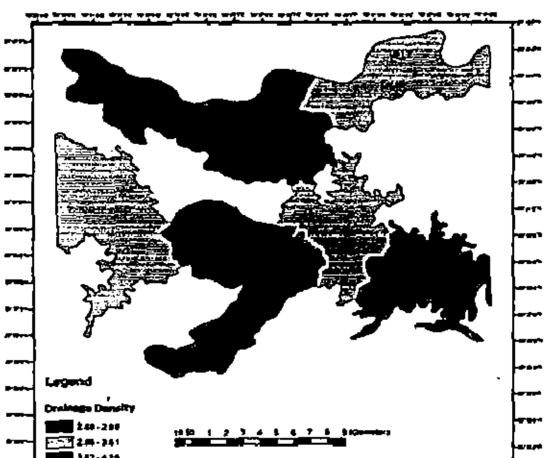

Figure 9: Classification of Drainage Density

)rainage Density (Dd): It is important indicator of the linear cale of land form element in stream eroded topography is lrainage density was introduced by Horton (1932). Areas with ıigh drainage density mean that it takes time for water to drain o a primary stream and time to arrive at secondary treams.Carlston (1963) showed that an inverse relationship :xists between drainage density and base flow. This is related o permeability of rock type present in the area. Greater the juantity of water moves on the surface of the system, the nigher the drainage density which inturn means that the ›aseflow is low (Bell, 2003). In general low drainage density s favored in regions of highly permeable subsoil material, ınder dense vegetation cover and where relief is low. High lrainage density is favored in regions of weak or impermeable :ubsurface materials, sparse vegetation and mountain relief Chow 1964). The low drainage density is also indicative of elatively long overland flow of surface water (Rao et., al. !011). Langbein (1947) suggested a drainage density varying ›etween 0.55 and 2.09 km/km2 in humid region with an ıverage density of 1.03 km/km^2.The drainage density in the :tudy area varies between 2.60 and 4.36 km/km^2 (Table.4) vhich suggests that the study area is plain with 1.03 with ıighly alluvium loaded streams (Dynowska, 1971) due to mpermeability of sub-surface and also may be due to high :inuosity (Bratsev, 1964). Higher values are found in CH-II ınd III while low value is obtain in sub-watershed KW-III Fig.10) indicating permeability in this sub-watershed. Semi og plot give a scatter plot of drainage density and stream requency (fig.11).

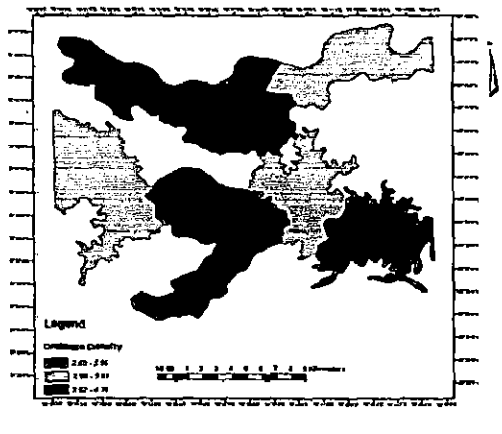

Figure 10: Classification of Drainage Density

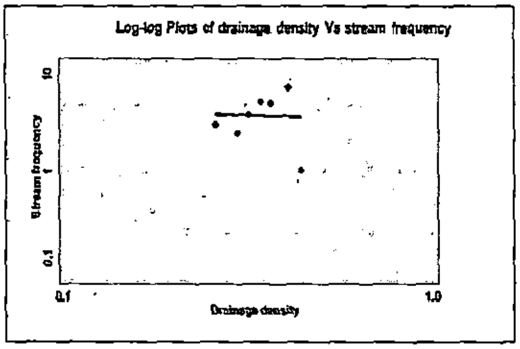

Figure 11: Graphical representation of Drainage Density vs Stream Frequency

Drainage Texture: According to Horton (1945), drainage texture is the total no. of stream segments of all orders per unit perimeter. Smith (1950) classified drainage density into five different drainage textures. The Dd less than 2 indicates very coarse, between 2 and 4 is related to coarse, between 4 and 6 is moderate, between 6 and 8 is fine and greater than 8 is very fine drainage texture. Sub-watershed KW-I, II and CH-I fall in moderate, while KW-III IV and CH-III falls in fine and CH- II falls in very fine texture category (Table.4, Fig.12) indicating impermeable sub-surface, soft and weak lithology (Ansari et., al. 2012). Soft and weak surface unprotected with vegetation produce fine texture whereas massive and resistant rock forms coarse texture. In the study area the thick unconsolidated alluvial and vegetation cover produces moderate to very fine texture of drainage.

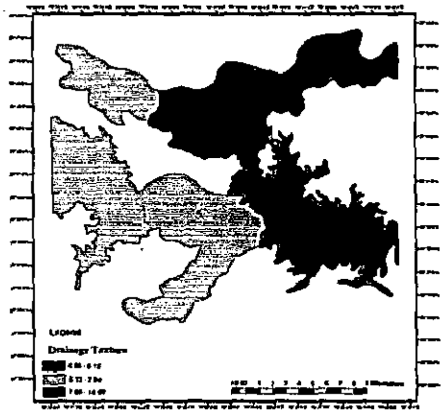

Figure 12: Classification of Drainage Texture

Infiltration Number (If): Infiltration number plays a significant role in observing the infiltration characters of drainage basin. High values of infiltration number in all the sub-watershed indicate low infiltration and high runoff (Table.4). The values also suggest that the condition of gully erosion would be further aggravated due to high runoff potential of the area. Highest value is obtained in CH-II (Fig.13) which also has high texture and density of streams. These factors together make this watershed prone to sever soil erosion by water.

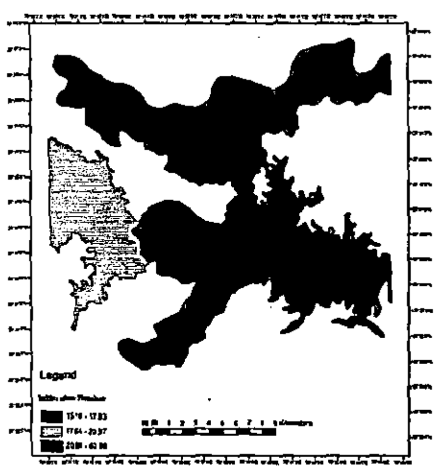

Figure 13: Classification of Infiltration Number

Length of Overland Flow (Lg): Horton (1945) defined length of overland flow as the length of flow path, projected to the horizontal, of non channel flow from point on the drainage divide to a point on the adjacent stream channel. Length of Overland Flow is the length of water over the ground before it gets concentrated indefinite stream channels (Horton, 1945). If the basin is well drained the value of overland flow is short and the surface runoff gets concentrated quickly and in all probability the minimum flow is correspondingly low. The overland flow is higher in semi-arid region than and humid temperate region due to lack of vegetation cove in semi arid region (Kale and Gupta, 2001). Table 4 reveals that length of overland flow in is high in all the sub-watershed with CH-II (40.00) having the highest value since density is highest in this sub-watershed.

C. Relief Aspects of Channel Network

Maximum Basin Relief (H): It is the elevation difference between basin mouth and the highest point on the basin perimeter. It is very important factor to obtain the potential energy of drainage system. The values of maximum basin relief for drainage basins were determined and presented in the Table-5. Elevation as high as 163m and as low as 106m has been found in the study area (Fig.14)

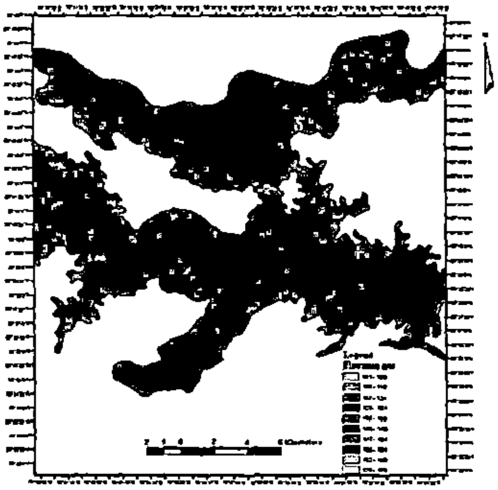

Figure 14: Elevation Map of the watershed

Name of Basin	Elevation		Max Basin Relief (km)	Relief Ratio	Relative Relief (Rhp)	Ruggedness Number (HD)
	Source point (m)	End Point (m)				
CH-I	160	106	0.054	0.006	0.15	0.17118
CH-II	159	120	0.039	0.004	0.12	0.156
CH-III	160	112	0.048	0.005	0.19	0.20928
KW-I	157	125	0.032	0.003	0.05	0.0944
KW-II	158	124	0.034	0.003	0.07	0.12274
KW-III	163	125	0.038	0.003	0.08	0.0988
KW-IV	162	128	0.034	0.002	0.06	0.1156

Table: 5. Elevation Parameters

Relief Ratio (Rh): Relief ratio measures the overall steepness of a drainage basin and is an indicator of the intensity of erosion process operating on slope of the basin (Schumm, 1954). High value of relief ratio indicate steep slope and high relief while small value may indicate the presence of basement rock that are exposed in the form of small ridge and mount with lower degree of slope (GSI, 1981). The values of Rh ranges between 0.002 (KW- IV) to 0.006 (CH-I) in study area (Table-5). Relief ratio is higher in Chambal sub-watershed and lower ratio is found in Kunwari sub-watersheds. Slope is upto 16^0 in Chambal basin while that of Kunwari ranges between0-13^0 in most part of sub-watershed (Fig. 15). This tells about the greater erosion of Chambal basin in general since steep slope and high relief favors erosion.

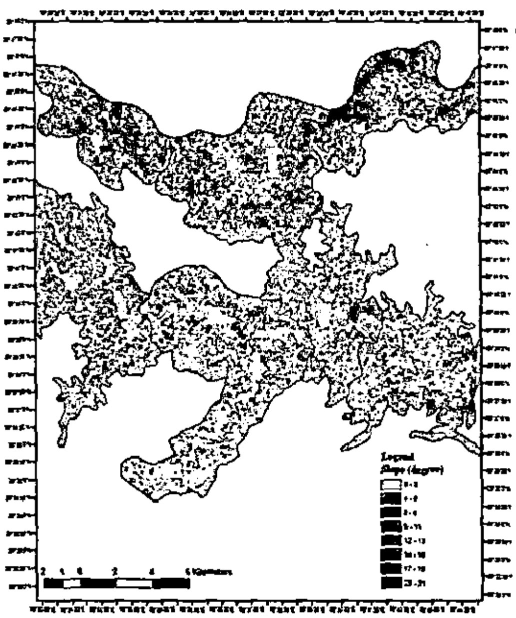

Figure 15: Slope Map of the watershed

Relative Relief (Rhp): This term was used by Melton, (1957). The relative relief of different drainage basins were determined and presented in table 5 and it is noted that relative relief is high in Chambal sub-waters and low in Kunwari sub-watersheds.

Ruggedness Number (HD): Extreme high values of ruggedness number occur when both variables are large, this is, when slope are not only steep but long as well (Strahler, 1958). The value of ruggedness no. ranges from 0.09 to 0.20, which is high. Higher value of ruggedness number speaks about uneven topography, lithological heterogeneity of terrain and high amount of dissection while moderate value indicate flat topped surface or ridge and valley topography and moderate to moderately high degree of dissection while lower values are found in the area of less dissection and leveled surface (Govind, 2007). High value to ruggedness number is found in all the sub-watershed Chambal with CH-III having the highest value while that of Kunwari sub-watersheds have lower values suggesting more dissection and ruggedness in Chambal basin than Kunwari.

CONCLUSION

The morphometric parameters suggests that CH-II has most unconsolidated thick surface cover with impermeable sub-surface lithology which results into high surface runoff making this sub-watershed more prone to sever soil erosion by surface water. The study area is covered by thick alluvium cover with high runoff potential, require taking preventive measure in order to avoid further loss of soil and reclaim the affected region. In general Chambal sub-watershed are more rugged and plaque by ravines than Kunwari sub-watersheds. The present study clearly indicates that Chambal river and its tributaries largely affected by sever soil erosion.

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